W472-TAO-002-90

UNCLASSIFIED

FINAL REPORT

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN (U)

MAY 1990

19980302 069

VOLUME 3
DATABASE REPORTS

CONTRACT NO: 86-N194100-000

TECHNOLOGY ASSESSMENT OFFICE

TRW
DEFENSE SYSTEMS GROUP
SPECIAL PROGRAMS
ONE SPACE PARK . REDONDO BEACH . CALIFORNIA 90278

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Report Number: W472-TAO-002-90
Accession Number: 2900
Title: Survey of Advanced Technologies in
Japan, Vol. 3: Database Reports
Personal Author: Kanarek, S.; Smitha, P.; Mecherle,
S.; Cantafio, L.; et al.
Contract Number: 86-N194100-000
Corporate Author or Publisher: TRW, Special Programs, Technology
Assessment Office, Redondo Beach, CA
Publication Date: May 01, 1990
Pages: 00490
Descriptors, Keywords: Technology Assessment Japan
Aerospace Communication Laser Sensor
IR FPA X-ray Lithography Diamond
Status Data Panel Resolution Speed

W472-TAO-002-90

UNCLASSIFIED

COPY NO: U01
TOTAL PAGES: 494

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Advanced Studies

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PREFACE

This document is the third of five volumes that comprise TRW's final report on the Survey of Advanced Technologies in Japan. It contains a complete set of printouts of only the unclassified entries, which comprise the major portion of this database. Actually, the database consists of ten separate databases (of identical structure) one for each of the technologies investigated.

This is a complex database, and it is strongly advised that users first review Volume 1 (document no. W472-TAO-001-90), in its entirety, to acquaint themselves with the features and structure of the database before attempting to utilize the material in this volume. Users who are unfamiliar with any of these technologies or sub-technologies should also first review the tutorials that appear for each in the Entry Notes Report (Memo Fields), contained in this volume. Those tutorials are the first memo field reports listed under each technology, and are always headed by the name of the technology or sub-technology. A complete set of tutorials is also contained in Volume 2.

This volume contains a separate package for each of the ten technologies. Each of those packages consists of six parts which are briefly described below.

The cover sheet specifies the technology and lists the sub-technologies that have been identified and investigated. The CTL number listed with each sub-technology is the basic code used to store, sort and recover each record within the database. As explained in the first volume, the CTL number is related to the numbering system employed in the DOD Militarily Critical Technology List.

The second part of each package is the Summary Report, which, in this case, lists all of the unclassified entries contained in that technology database. It provides some key information about each entry, including the CTL and sheet numbers, the achievement rank, whether the entry is a primary or secondary one, and the name of the principal organization involved.

The third part of each technology package is the Parameter Names Report, which identifies the different parameters, for each sub-technology, that have been used to evaluate itsstatus in Japan. It lists the parameter name, the units of measure, and the direction of improvement, for each of up to six parameters, for each sub-technology.

The fourth and fifth part of each package are the database entry reports, for primary and secondary records respectively. They contain the parameter values and notes extracted from the source materials used in this investigation. Volume 1 contains an explanation of how primary and secondary reports are cross-referenced through the REF number in the database.

The sixth part of each package is the Entry Notes Report, that contains excerpts from the original source documents.

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX A

VOICE & DATA COMMUNICATIONS ENCRYTION (VDCE)

0901010A04 - VDCE - SYSTEM PERFORMANCE

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01/04/93

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION								
09010 10A04	A	BL		B	A0000		Y	
09010 10A04	A	JA	E	P	A011A	P	Y	HITACHI LTD., SYSTEMS DEVELOPMENT LABORATORY
09010 10A04	A	JA	E	P	A005A	P	Y	KOKUSAI DENSHIN DENWA CO., LTD., KAMIFUKUOKA R&D LABORATORIES
09010 10A04	A	JA	E	P	A006A	P	N	KYUSHU INSTITUTE OF TECHNOLOGY, FACULTY OF COMPUTER SCIENCE AND SYSTEMS ENG.
09010 10A04	A	JA	B	P	A013A	P	Y	MATSUSHITA ELECTRIC INDUSTRIAL CO. LTD.
09010 10A04	A	JA	B	P	A004A	P	Y	NEC CORPORATION, C&C INFORMATION TECHNOLOGY RESEARCH LABORATORIES
09010 10A04	A	JA	E	P	A007A	P	Y	THE UNIVERSITY OF ELECTRO-COMMUNICATIONS
09010 10A04	A	JA	B	P	A001A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL & ELECTRONIC ENGINEERING
09010 10A04	A	JA	B	S	A002A	A001A	N	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL & ELECTRONIC ENGINEERING
09010 10A04	A	JA	B	P	A011B	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL AND ELECTRONIC ENGINEERING
09010 10A04	A	JA	E	P	A008A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF INFORMATION PROCESSING, GRADUATE SCHOOL

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01/04/93

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JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
09010 10A04	A	JA	C	P	A003A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, GRADUATE SCHOOL AT NAGATSUTA
09010 10A04	A	JA	E	P	A012A	P	Y	UNIVERSITY OF TOKYO, DEPT. OF ELECTRICAL ENGINEERING
09010 10A04	A	JA	E	P	A009A	P	Y	WASEDA UNIVERSITY, DEPT. OF ELECTRONICS & COMMUNICATION ENGINEERING
09010 10A04	A	JA	E	P	A010A	P	Y	YOKOHAMA NATIONAL UNIVERSITY, DIVISION OF ELECTRICAL & COMMUNICATION ENGINEERING

** *** SUB-TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION (CONTINUED)

09010 10A04	B	BL		B	A0000		Y	

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION							
09010 10A04 A VDCE	VOICE OR DATA SYSTEM --- NONE --- IMPR. DIR: X	SYSTEM TYPE --- NONE --- IMPR. DIR: X	ENCIPHER KEY PERIOD --- MILLION CHARACTERS --- IMPR. DIR: H	ENCRYPTION ROUNDS --- NONE --- IMPR. DIR: H	CIPHERTEXT ATTACK RESISTANCE --- HIGH, MODERATE OR LOW --- IMPR. DIR: H	PLAINTEXT ATTACK RESISTANCE --- HIGH, MODERATE OR LOW --- IMPR. DIR: H	SYS PERF
** ******************** SUB-TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION (CONTINUED)							
09010 10A04 B VDCE	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
## ############### SUB-TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION												
09010 10A04 A VDCE 13	E	HITACHI LTD., SYSTEMS DEVELOPMENT LABORATORY ---- KAWASAKI, JAPAN ---- K.TAKARAGI, T.SHIRAISHI & R.SASAKI ----	---- ---- ----	---- ---- ----	Y A DT U	DATA ----	DIGITA L TALLY ----	----	----	----	----	JEU/10- 06-86/0 102 10/06/8 6 A011A / / JA
09010 10A04 A VDCE 7	E	KOKUSAI DENSHIN DENWA CO., LTD., KAMIFUKUOKA R&D LABORATORIES ---- SAITAMA 356, JAPAN ---- KOUJI NAKAO & KENJI SUZUKI ----	---- ---- ----	---- ---- ----	Y A DT U	DATA ---- SEE MEMO	----	----	----	----	----	JDS/VOL 7 #4/0505 05/01/8 9 A005A / / JA
09010 10A04 A VDCE 8	E	KYUSHU INSTITUTE OF TECHNOLOGY, FACULTY OF COMPUTER SCIENCE AND SYSTEMS ENG. ---- IIZUKA, KUKUOKA 820, JAPAN ---- K.IMAMURA ---- THIS ARTICLE IS A MATHEMETICAL MODEL ONLY, ARTICLE ONLY MENTIONED DUE TO ACTIVTY IN THIS TECHNOLGY	SAGA UNIVERSITY, FACULTY OF SCIENCE & ENGINEERING ---- SAGA 840, JAPAN ---- S.MATSUFUJI ----	---- ---- ----	N A DT U	DATA ---- ARTICL E ENTITL ED: "THE NUMBER OF SELF-C OMPLEM ENTARY BASES OF A DEFINI TE FIELD OF CHARAC TERIST IC TWO"	----	----	----	----	----	JEU/06- 19-86/0 209 06/19/8 6 A006A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
09010 10A04 A VDCE 16	B	MATSUSHITA ELECTRIC INDUSTRIAL CO. LTD. ---- 1006, KADOMA OAZA KADOMA, OSAKA 571, JAPAN ---- M.TATEBAYASHI & N.MATSUZAKI ---- VISITING SCHOLAR AT THE GEORGE WASHINGTON UNIVERSITY, TEAM WITH DAVID B. NEWMAN JR. DEPT. OF EE&CS	---- ---- ----	---- ---- ----	Y A DT U	VOICE ----	ANALOG ----	----	----	HIGH ----	HIGH ----	?/CH266 5/1145 09/01/8 9 A013A / / JA
09010 10A04 A VDCE 6	B	NEC CORPORATION, C&C INFORMATION TECHNOLOGY RESEARCH LABORATORIES ---- 4-1-1 MIYAZAKI, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- EIJI OKAMOTO & KAZUE TANAKA ----	---- ---- ----	---- ---- ----	Y A DT U	DATA ----	ID BASED - KDS ---- SEE MEMO	----	----	HIGH ---- TO AUTHOR S THEORE TICALL Y HIGH RESIST ANCE BUT DIFFIC ULT TO PROVE	HIGH ---- TO ATUTHO RS THEORE TICALL Y HIGH RESIST ANCE BUT DIFFIC ULT TO PROVE	JDS/VOL 7 #4/0481 05/01/8 9 A004A / / JA
09010 10A04 A VDCE 9	E	THE UNIVERSITY OF ELECTRO-COMMUNICAT IONS ---- CHOFU, TOKYO 182, JAPAN ---- HIROSUKE YAMAMOTO ----	---- ---- ----	---- ---- ----	Y A DT U	VOICE ----	SSCS ---- SEE MEMO	----	----	----	----	JAU/06- 19-88/0 211 06/19/8 8 A007A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
09010 10A04 A VDCE 3	B	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL & ELECTRONIC ENGINEERING ---- TOKYO 152, JAPAN ---- SHIGEO TSUJII & TOSHIYA ITOH ----	---- ---- ----	---- ---- ----	Y A DT U	DATA ---- SEE MEMO	RSA ----	----	----	----	----	JDS/VOL 7 #4/0467 05/01/8 9 A001A / / JA
09010 10A04 A VDCE 14	B	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL AND ELECTRONIC ENGINEERING ---- 2-12-1, O-OKAYAMA, MEGURO-KU, TOKYO 152, JAPAN ---- S.TSUJII, K.KUROSAWA, T.ITOH, A.FUJIOKA ----	YOKOHAMA NATIONAL UNIVERSITY, DEPT. OF ELECTRICAL AND ELECTRONIC ENGINEERING ---- TOKIWADAI, HODOGAYA-KU, YOKOHAMA 240, JAPAN ---- T.MATSUMOTO ----	---- ---- ----	Y A DT U	DATA ---- SEE MEMO	PUBLIC KEYSYS TEM ----	----	----	HIGH ----	HIGH ----	JEU/10-06-86/0 102 10/06/8 6 A011B / / JA
09C10 10A04 A VDCE 10	E	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF INFORMATION PROCESSING, GRADUATE SCHOOL ---- 4259 NAGATSUTA, MIDORI-KU, YOKOHAMA 227, JAPAN ---- K.KUROSAWA, T.ITO & M.TAKEUCHI ----	---- ---- ----	---- ---- ----	Y A DT U	----	RSA-PU BLIC KEY ----	----	----	----	HIGH ---- ACCORD ING TO AUTHOR OF THIS ARTICL E	JEU/06-19-88/0 230 06/19/8 8 A008A / / JA
09010 10A04 A VDCE 5	C	TOKYO INSTITUTE OF TECHNOLOGY, GRADUATE SCHOOL AT NAGATSUTA ---- YOKOHAMA 227, JAPAN ---- K. KUROSAWA ----	---- ---- ----	---- ---- ----	Y A DT U	DATA ----	RSA ----	----	----	LOW ----	----	JDV/VOL 25 #9/0577 04/27/8 9 A003A 12/21/8 8 JA

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TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
09010 10A04 A VDCE 15	E	UNIVERSITY OF TOKYO, DEPT. OF ELECTRICAL ENGINEERING ---- 7-3-1 HONGO, BUNKYO-KU, TOKYO 113, JAPAN ---- T.MATSUMOTO ----	YOKOHAMA NATIONAL UNIVERSITY ---- 156, TOKIWADAI, HODOGAYA-KU, YOKOHAMA 240, JAPAN ---- Y.TAKASHIMA & H. IMAI ----	---- ---- ----	Y A DT U	DATA ----	PUBLIC KEY SYSTEM ----	----	----	----	----	JEU/10-06-86/0 103 10/06/8 8 A012A / / JA
09010 10A04 A VDCE 11	E	WASEDA UNIVERSITY, DEPT. OF ELECTRONICS & COMMUNICATION ENGINEERING ---- 1-3-4 OHKUBO SHINJUKU-KU, TOKYO 160, JAPAN ---- N.ROSARIO, N.KOMATSU & H.TOMINAGA ----	---- ---- ----	---- ---- ----	Y A DT U	DATA ---- SEE MEMO	PIN ----	----	----	----	----	JEU/06-19-88/0 231 06/19/8 8 A009A / / JA
09010 10A04 A VDCE 12	E	YOKOHAMA NATIONAL UNIVERSITY, DIVISION OF ELECTRICAL & COMMUNICATION ENGINEERING ---- 156 TOKIWADAI, HODOGAYA, YOKOHAMA 240, JAPAN ---- T.MATSUMOTO & H.IMAI ----	---- ---- ----	---- ---- ----	Y A DT U	VOICE & DATA ----	KEY PREDIS TRIBUT ION SYSTEM ----	----	----	----	----	JAU/06-19-88/0 232 06/19/8 8 A010A / / JA

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DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTT
** *************** SUB-TECHNOLOGY: VOICE & DATA COMMUNICATIONS ENCRYPTION												
09010 10A04 A A001A VDCE 4	B	TOKYO INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL & ELECTRONIC ENGINEERING ---- TOKYO 152, JAPAN ---- S. TSUJII & T. ITOH ----	KOBE UNIVERSITY, DEPT. OF ELECTRICAL ENGINEERING ---- KOBE 657, JAPAN ---- H. TANAKA ----	---- ---- ----	N A DT U	DATA ----	RSA ----	----	----	HIGH ----	HIGH ----	JDV/VOL 25 #1/077 01/05/8 9 A002A 10/11/8 8 JA

Record# PAGENO DESCRAPPLC
1 A0000

VOICE & DATA COMMUNICATIONS ENCRYPTION

Purposes for encryption are privacy, security and authentication. Quality of an encryption system is measured by its resistance to the following cryptanalytic attacks: ciphertext only attack, known plaintext attack, chosen plaintext attack.

In a ciphertext attack the analyst knows only the ciphered message and he uses the statistical properties of the language as well as probable words ("Sincerely yours" in letter closing). In English, for example, the letter E appears 13% of the time while Z appears 0.1%, and there are conspicuous letter pairs (digrams) and letter triples (trigrams).

A known plaintext attack takes advantage of the rigid structures of formal structures used in programming, or of data such as business forms and the use of probable words such as "procedure" and "integer". The analyst can thus assume and search for many words in the message, based upon the message type, its origin or its destination.

A chosen plaintext attack is easiest since the analyst has seen the ciphertext for a plaintext of his choosing.

A encryption system that cannot be deciphered regardless of the computing power available to the cryptanalyst is called "unconditionally secure", while a system that is theoretically capable of being broken, but would require an effort that would exhaust the computing resources of the opponent, is considered to be "computationally secure". The only unconditionally secure system in common use is a "one time tape" in which the plaintext is combined with a totally random key of the same length, which is never reused.

Encryption Keys

The "key" is the mechanism of encryption and decryption and there are 11 major types, 10 of which apply solely to data encryption. Only J. Analog Systems (below) deals with voice encryption. The ideal key is small, easily and securely distributed to all users and easily changed when compromised.

A. SUBSTITUTION - is the simplest technique, in which the key is a permuted alphabet and the letters from that corresponding alphabet are substituted for those in the message. It is easily solved by letter frequency tables, digrams and trigrams.

B. TRANSPOSITION - breaks the message into character groups (eg. 5) and transposes the characters in each group according to a permutation table such as an example that specifies that the 3rd character of each group be written first, the first character be written second, and so on. By itself, this technique can easily be solved with letter frequency tables, digrams and trigrams.

C. POLYALPHABETIC CIPHERS - employs a number of substitution alphabets that are used periodically, for example, six alphabets would be used, in order, for each of the first six characters of the message, and again for the next six, and so on. A multiple loop system (called Vigenere) could use a different quantity of substitution alphabets to "superencipher" the resulting

ing key directory or a public key directory. All a user has to keep is his IC card, which was distributed when first joining the network. Key distribution systems using only one-way communication, such as Blom's system, actually need an ID list because exact bit patterns of the ID's are effective.

3) When a new user joins, other users need not renew their cards, unless they want to communicate with the new user in one-way communication.

4) Even if some user's secret information were to be exposed, other users' secret information would still remain secure.

5) The work keys are randomly determined. In the DH-PKDS, work keys between two fixed users are always a constant.

6) All users have the same modulus n, although in the RSA cryptosystem each user uses a different modulus n. This property is useful for implementing modular exponentiation.

Because of these advantages, it is convenient to apply the ID-based KDS to any

9 A007A

TITLE: CODING THEOREM FOR SECRET SHARING COMMUNICATION SYSTEMS WITH TWO NOISY CHANNELS

In order to obtain safe information transmission via several parallel channels, the secret sharing communication system (SSCS) was considered as an extension of Shannon's cipher system in a previous paper. Although the coding theorem was proved for t he SCCS with two or three channels, the considered channels were assumed noiseless.

3 A001A

In a modern network system, data security technologies such as cryptosystems, signature schemes, etc., are indispensable for reliable data transmission. In particular, for a large-scale network, ID-based systems such as the ID-based cryptosystem, the ID-based signature scheme, or the ID-based key distribution system are among the better countermeasures for establishing efficient and secure data transmission systems. The concept of an ID-based cryptosystem has been proposed by Shamir, and it is advantageous to public-key cryptosystems because a large public-key file is not required for such a system.

This paper proposes an ID-based cryptosystem based on the discrete logarithm problem, which is one of the earliest realizations in Shamir's sense. Furthermore, we consider the security against a conspiracy of some entities in the proposed system, and show the possibility of establishing a more secure system.

4 A002A MODIFIED ID-BASED CRYPTOSYTEM USING DISCRETE LOGARITHMPROBLEM

The authors have shown that Laih and Lee's modified ID-based cryptosystem is not secure as they expected. Thefinal goal regarding the ID-based cryptosystem is toestablish a secure system in a strict sense, whichimplies that the number of entities to disclose thetrusted centre's (TC) secret information is much higherthan the number of the TC's secret information.

14 A011B

TITLE: A PUBLIC-KEY CRYPTOSYSTEM BASED ON THE DIFFICULTY

by using the underlying ACSE authentication procedure. Regarding realization of data integrity and confidentiality, the SCSE transfer is introduced to cover all the requirements for these services to the extent of selective field services and recovery from integrity errors. Especially in the case of confidentiality, we decided to make use of encrytion/dycryption functionalities of the present layers without any modification. For the three services listed above, it is also better to highlight that SCSE architecture provides the very simple interface to the user; that is, the SCSE user does not need to indicate the detailed security functions and the mechanisms to the SCSE and only needs to indicate the functional units to be used.
Both the service definition and protocol specification of the SCSE have been described in this paper. The SCSE can therefore be put into practical use for existing and future OSI specific applications in order to realize secure communications.

8 A006A
16 A013A

A CRYPTOSYSTEM USING DIGITAL SIGNAL PROCESSORS FOR MOBILE COMMUNICATION

A voice cryptosystem based on PN sequence generator is proposed for the digital mobile communication system. The periodicity and linear complexity of the key system is analyzed. An initial value of a control register determines one of a large number of periodic sequence.

6 A004A

A key distribution system based on identification information (ID-based KDS) is presented. The system is founded on the Diffie-Hellman public key distribution scheme and has an identity authentication function. It uses an individual user's identification information instead of the public file used in the Diffe-Hellman scheme. It does not require any services of a center to distribute work keys or users to keep directories of key-encrypting keys. Therefore, key management in cryptosystems can be simplified by adopting the ID-based KDS. In this paper, two kinds of identity based key distribution system are proposed and applied to actual communication networks. One uses two-war (interactive) communication to distribute work keys. while the other uses one-way communication. Modular exponentiations of large numbers, used in the systems, are implemented with digital signal processors.

Conclusion

Two ID-based KDS's have been proposed. They have the following merits.

1) They do not require any key distribution center or arbitrators to be active in each communication. Only a card issue center is needed when starting up a network. The center can be closed after it has distributed cards to all users. The top secret number d, or prime numbers p and g on adopting Rabin's scheme, can be eliminated.

2) An individual user need not maintain a key-encrypt-

cryptogram, yielding a period much longer than the period of either component. Both ciphers can be solved by factoring the message to identify the periods and then solving the individual substitution alphabets with the classical tools.

D. RUNNING KEY CIPHER - uses the text from any book, starting on page no. x, line no. y as a key. The plaintext message and this key are added, character-by-character, mod-26 (a=0, b=1, z=25) to produce the ciphertext. It is decrypted by subtracting the key from the ciphertext mod-26. This technique is solved by the probable word, common word, and common character group (eg. tion) approaches. Subtracting these from all possible positions will expose words in the key. Another approach looks at the highest- probability resultant pairs for each character.

E. CODES - this is a book of random numbers and letters combined to form "codegroups" that represent words and phrases. While the key is very large, it is very difficult to break and provides data compression. When heavily used it can be solved by frequency analysis and known plaintext attack.

F. HAGELIN MACHINE - U.S. WW II code machine uses six keywheels with 26, 25, 23, 21, 19 & 17 teeth each, with corresponding pins at every tooth. The pin position indicates either a 0 or 1 bit and the combination of 6 bits from the 6 keywheels identifies a character for each setting of the keywheels. A keystream of characters, produced by advancing the wheels one position, is subtracted from the plaintext mod-26 to produce ciphertext. This device provides a 101 million character-long pseudorandom key.

(SEE CONTINUATION ON SHEET B OF SAME CTL)

13 A011A

Suppose that two persons, A and B, are going to sign a contract over a communication network with a security center which can function in troubled situations. Our major concern is how to safely exchange the digital signatures under the limited computer and transmission loads in both the normal exchange and the arbitration of troubles. Digital signatures, first introduced by Diffe and Hellman, can be proof of contract agreement after they have been exchanged. In our protocol, three ciphers , i.e., B's, "digital tally", A's formal digital signature and B's formal digital signature are transmitted in order. "Digital tally" is a kind of digital signature but does not satisfy the prescribed format for the format contract. The arbitration functions of the security center are chosen to solve the problems. When intended commitment or unintended human error occurs "digital tally" is used to prove where and by whom the error has occurred.

7 A005A

With the increasing demand for secure communications, the existing techniques cannot fulfill the requirements for security satisfactorily.
This paper proposes a Secure Communications Service Element (SCSE) in the OSI Application layer as a new common application-service element to realize OSI secure communications. The basic security services (that is, peer entity authentication, data integrity, and data confidentiality) are taken into consideration in the SCSE. As for the peer entity authentication service, we clarify the relationship between the parameters defined in ACSE and the information defined in the basic authentication mechanisms, and propose an overall authentication protocol between the peer SCSE

------.
OF SOLVING A SYSTEM OF NON-LINEAR EQUATIONS

Only a few public-key cryptosystems have been proposed, and these possess disadvantages such as the need for intensive computation. For example, RSA requires O(m^3) operations, where m is the message block size. We proposed a public key cryptosystem, which is based on a set of non-linear equations, and which requires less computation but more memory that RSA. The proposed system has the following properties:

1. The computational complexity of encryption and decryption are O(m^2).

2. A digital signature is possible.

Two methods of attack against the cryptosystem are considered. It is shown that both require an excessively large number of computations when the key bit size K>= 6. The system is suitable for hardware realization because encryption and decryptation are performed in GF(2^t). Since the public key is constructed by simple arithmetic operations, fast transformation is achieved by parallel or pipeline processing.

10 A008A

TITLE: PUBLIC KEY CRYPTOSYSTEM USING A RECIPROCAL NUMBER WITH THE SAME INTRACTABILITY AS FACTORING A LARGE NUMBER

A public key cryptogystem proposed by Rabin is excellent because it has been proven that breaking the cryptosystem is as hard as factoring a large number. However, a ciphertext cannot be unique deciphered because four different plaintexts produce the same cipher. Williams showed that this disadvantage can be overcome if the secret two prime numbers, p and q, are chosen such that p=q=3 mod 4.

RSA cryptosystem is the most well-known public key cryptosystem. However, it is not known whether breaking RSA cryptosystem is as hard as factoring a large number. RSA scheme requires O(n^3) bit operations for both encryption and decryption (where n is the bit length of a plaintext).

This paper proposes a public key cryptosystem using a reciprocal number. Breaking the proposed cryptosystem is proven to be as difficult as factoring a large number. Encryption requires only O(N^2) bit operations and decryption requires O(n^3) bit o perations. The secret two prime numbers, p and q, are arbitrary, which is a great advantage over Williams version of Rabin's cryptosystem.

5 A003A

KEY CHANGEABLE ID-BASED CRYPTOSYSTEM

ID-based public key cyrptosystems and ID-based signature systems have been proposed. Users can change their key parameters by themselves easily with no help from the centre, Their is no threat of user conspiracy.e

15 A012A

TITLE: CRYPTO-KEY SHARING AMONG MULTIPLE USERS

This paper proposes and analyzes a public-key scheme that brings a common crypto-key to each member of a specified group of users. "Registered data" contained in the public file and the "transferred data" exchanged between pairs of members play a

significant role in the scheme. The system is based on the commutative and homomorphic properties of power functions over a finite field. Some of its features are as follows:

1. Generation of the key by a non-member is extremely difficult.
2. Different keys can be shared in a fixed group for every data transfer, without updating the public file.
3. Operation of the scheme is symmetric respective to its various members.
4. The scheme is robust relative to the addition of new group members.
5. Since data transfer from different members can occur simultaneously, efficient key sharing is possible, e.g., by spread spectrum techniques.

11 A009A

TITLE: PERSONAL IDENTIFICATION NUMBER GENERATION USING FINGERPRINT

Human identification for system security is an important subject, and one solution in keeping the system security is through the use of PIN (Personal Identification Number). The manner of obtaining this PIN which a third party cannot forge and the means of using this PIN as key for access control or data encryption and the likes are in great demands.

In this paper, we propose a new concept of generating one's PIN which will be used to identify him. This is a round scanning scheme on fingerprint image for extracting a sequence of pattern. The round scanning is flexible for matching images at different axis of orientation because by simply shifting the scanned data we are in effect rotating the image being compared to have the same axis of orientation with the other one. We also propose a PIN data matching process using the characteristics of round-scanned-data.

12 A010A

The Key Predistribution System (KPS, for short) matches the features of today's and near future's cryptographic communications in large open networks. The KPS is a mechanism, which brings, on request, a common key to each member of any group of specified entities in a network, without previous communications among the group nor accesses to any public key directory or whatsoever. The network can be very large but is assumed to have one or several managing centers. Applying the KPS, we can obtain simple but powerful and practical methods achieving various information security which could never been realized by the conventional common-key nor public-key systems alone. This paper proposes "linear schemes" for the KPS, and investigates their security and implementation methods on smart-cardbased systems. Each linear scheme is based on a multi-linear mapping defined over modules over a ring. Our conclusion is that these linear schemes are secure and practical.

2 A0000

VOICE & DATA COMMUNICATIONS ENCRYPTION (CONTINUED)

G. ROTOR MACHINES - contain a bank of rotors (small thick disks) with a mechanism for rotating their position each time a character is enciphered. Each rotor contains as many positions and electrical contacts on its edge) as letters of the alpha bet (26. or 128 for ASCII) and each position is position is

"wired" to permute to another character on that rotor. These rotors can be connected in series so that a character being enciphered passes through each rotor, being repermuted by each rotor. The rotor positions must change for the next character and
the simplest rotor mechanism is like an odometer, but it is not very secure because usually only one rotor changes position. Another technique is to move all rotors each time and to design the mechanism so that the period of each rotor is different, similar to the Hagelin machine and with 6 rotors the total period is 101 million, same as the Hagelin machine. The machine is supplied with more rotors than it can hold. It is keyed by choosing the rotors and their position in the bank.

H. SHIFT REGISTERS - In the provably secure one-time-tape cipher, the key is totally random string of bits that is XORed (added mod-2) with the plaintext, which has been first converted to binary form. The key must be as long as the message and cannot be
reused, which poses great inconvenience. There are computer techniques using feedback shift registers to produce a long, non-repeating, random-like, binary sequence (for this cipher) from a short key, which are called Maximal Length Shift Register Sequence
(MLSRS). Unfortunately, this technique can be broken in a few seconds on a minicomputer because it uses linear logic. A nonlinear feedback loop would provide greater security and has future promise.

I. IBM SYSTEMS AND DES - DES is the Data Encryption Stanadard adopted in 1977 by the National Bureau of Standards, and is an outgrowth of research performed by IBM, which was based on information theory. Using computer circuitry, this technique works on blocks of 8 characters (64 bits) of plaintext, and uses rounds" (iterations) of substitution and transposition by software mechanisms called "S-boxes" and "T-boxes". The initial 64 bits are divided into left and right halves of 32 bits each and then manipulated by a complex algorithm that performs 16 rounds of permutation (substitution and transposition). The security of this system is based on the complexity and extensive cost ($20 million in 1977) of a computer capable of breaking this cipher. Recent improvements in technology and cost reductions threaten its security.

J. ANALOG SYSTEMS - encryption of voice, facsimile or other analog communications is often accomplished by analog rather than digital means and is then called "scrambling". The simplest analog scramblers are frequency inverters, which have no key and their product can be unscrambled by anyone with another
machine. More complex analog devices are band splitters that break speech into 5 frequency bands and then permute them, but since they yield a maximum of 120 permutations, many of them similar, these messages are easily unscrambled. Rolling code scramblers change the permutation several times a second and also invert the frequency continuously, under the control of a pseudorandom number generator, which uses the key as a seed. Time
division scramblers break speech into short segments and permute the segments within blocks, and are also produced as two-dimensional scramblers that permute both time and frequency segments. Digital scramblers that used analog to digital converters on speech and then employ some form of digital encryption and the most secure and the easiest to design, but have been more costly than analog scramblers. Also, digital scramblers demand higher bandwidths of the communications link.

K. PUBLIC KEY DISTRIBUTION SYSTEMS - The need for secure distribution of keys between users is a constant problem and can be avoided by public key systems in which the sender and receiver agree upon a key, which the eavesdropper overhears, but is unable to compute the key. There are also such systems that employ separate keys for enciphering and deciphering. Some systems use a
public enciphering key but a secure deciphering key, which are constructed mathematically so that one cannot be derived from the other. Sophisticated mathematical techniques employed include:

a. computing logarithims over a finite field with a prime number q of elements under arithemetic mod-q

b. factoring the product of two large prime numbers

c. the "Trap Door Knapsack" using combinatorics

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX B

SPACE BASED LASER COMMUNICATIONS (SBLC)

0901020200 - SBLC - SYSTEM PERFORMANCE

0601010100 - Nd: YAG LASER

0601010400 - HIGH-POWER SEMICONDUCTOR DIODE LASER

0702040201 - SEMICONDUCTOR SILICON AVALANCHE PHOTODIODE

0702040202 - GaAs P-I-N PHOTODIODES

0702040203 - PHOTOMULTIPLIER TUBE (PMT)

13040A0100 - BEAM COMBINER FOR GaAs LASER DIODE

13040A0200 - TELESCOPE OPTICAL SYSTEM

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** *** SUB-TECHNOLOGY: Nd:YAG LASER								
06010 10100	A	BL		B	B0000		Y	BASELINE/TUTORIAL
** *** SUB-TECHNOLOGY: HIGH-POWER SEMICONDUCTOR DIODE LASER								
06010 10400	A	BL		B	B0000		Y	BASELINE/TUTORIAL
06010 10400	A	JA	C	P	B015B	P	Y	COMMUNICATION RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS
06010 10400	A	JA	C	P	B013A	P	Y	MATSUSHITA ELECTRONICS CORP., ELECTRONICS RESEARCH LABORATORY
06010 10400	A	JA	C	P	B008A	P	Y	MITSUBISHI ELECTRIC CORP., CENTRAL RESEARCH LABORATORY
06010 10400	A	JA	B	P	B012B	P	Y	MITSUBISHI ELECTRIC CORP., CENTRAL RESEARCH LABORATORY
06010 10400	A	JA	C	S	B001A	B015B	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN, (NASDA)
06010 10400	A	JA	C	P	B002A	P	Y	NEC CORP.
06010 10400	A	JA	B	S	B016A	B015B	Y	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION
06010 10400	A	JA	B	P	B003A	P	Y	OMRON TATEISI ELECTRONICS CO., CENTRAL R&D LAB.
06010 10400	A	JA	B	P	B005A	P	Y	SONY CORPORATION
06010 10400	A	JA	B	P	B005B	P	N	SONY CORPORATION

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06010 10400	A	JA	C	P	B005C	P	N	SONY CORPORATION
06010 10400	A	JA	C	P	B011A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, GRADUATE SCHOOL AT NAGATSUTA
** *** SUB-TECHNOLOGY: SEMICONDUCTOR SILICON AVALANCHE PHOTODIODE (APD)								
07020 40201	A	BL		B	B0000		Y	BASELINE/TUTORIAL
07020 40201	A	JA	E	P	B015C	P	Y	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS
07020 40201	A	JA	C	P	B004A	P	N	HAMAMATSU PHOTONICS K.K.
07020 40201	A	JA	D	P	B020C	P	Y	MINISTRY OF POSTS AND TELECOMMUNICATIONS, RADIO RESEARCH LABORATORIES
07020 40201	A	JA	C	P	B014A	P	Y	SHIZUOKA UNIVERSITY, GRADUATE SCHOOL OF ELECTRONIC SCIENCE AND TECHNOLOGY
** *** SUB-TECHNOLOGY: GaAs P-I-N PHOTODIODES								
07020 40202	A	BL		B	B0000		Y	BASELINE/TUTORIAL
** *** SUB-TECHNOLOGY: PHOTOMULTIPLIER TUBE (PMT)								
07020 40203	A	BL		B	B0000		Y	BASELINE/TUTORIAL
07020 40203	A	JA	D	P	B020D	P	Y	MINISTRY OF POSTS AND TELECOMMUNICATIONS, RADIO RESEARCH LABORATORIES

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** *** SUB-TECHNOLOGY: SPACE BASED LASER COMMUNICATIONS								
09010 20200	A	BL		B	B0000		Y	BASELINE/TUTORIAL
09010 20200	A	JA	E	S	B010A	B015A	Y	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS & TELECOMMUNICATIONS
09010 20200	A	JA	B	P	B015A	P	Y	MINISTRY OF POSTS AND TELECOMMUNICATIONS, COMMUNICATIONS RESEARCH LABORATORY
09010 20200	A	JA	C	P	B018A	P	Y	MINISTRY OF POSTS AND TELECOMMUNICATIONS, RADIO RESEARCH LABORATORIES
09010 20200	A	JA	A	P	B012A	P	Y	MITSUBISHI ELECTRIC CORP., CENTRAL RESEARCH LABORATORY
09010 20200	A	JA	B	S	B009A	B015A	Y	NEC CORPORATION
09010 20200	A	JA	D	P	B006A	P	Y	NEC CORPORATION - YOKOHAMA PLANT
09010 20200	A	JA	B	S	B017A	B015A	Y	NEC CORPORATION, SPACE & LASER COMMUNICATION DIVISION
09010 20200	A	JA	B	S	B016A	B015A	Y	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION
09010 20200	A	JA	C	P	B019A	P	Y	RADIO RESEARCH LABORATORIES
09010 20200	A	JA	C	S	B020A	B019A	Y	RADIO RESEARCH LABORATORIES, MINISTRY OF POSTS AND TELECOMMUNICATIONS
09010 20200	A	JA	D	S	B007A	B015A	Y	SCIENCE AND TECHNOLOGY AGENCY

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** *** SUB-TECHNOLOGY: BEAM COMBINER FOR GaAs LASER DIODES								
13040 A0100	A	BL		B	B0000		Y	BASELINE/TUTORIAL
** *** SUB-TECHNOLOGY: TELESCOPE OPTICAL SYSTEM								
13040 A0200	A	BL		B	B0000		Y	BASELINE/TUTORIAL
13040 A0200	A	JA	C	P	B015D	P	Y	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS
13040 A0200	A	JA	B	P	B020B	P	Y	MINISTRY OF POSTS AND TELECOMMUNICATIONS, RADIO RESEARCH LABORATORIES
13040 A0200	A	JA	C	S	B016C	B015D	Y	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION

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CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: Nd:YAG LASER							
06010 10100 A SBLC	WAVELENGTH --- u (MICRONS) --- IMPR. DIR: X	LASER POWER --- mW (MILLIWATT) --- IMPR. DIR: H	POWER CONVERSION EFFICIENCY --- % (PERCENT) --- IMPR. DIR: H	BEAMWIDTH/DIFFRACT ION LIMIT --- NONE --- IMPR. DIR: L	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: HIGH-POWER SEMICONDUCTOR DIODE LASER							
06010 10400 A SBLC	WAVELENGTH --- u (MICRONS) --- IMPR. DIR: X	LASER POWER --- mW (MILLIWATT) --- IMPR. DIR: H	POWER CONVERSION EFFICIENCY --- % (PERCENT) --- IMPR. DIR: H	ARRAY SIZE (PHASE LOCKED) --- ELEMENTS --- IMPR. DIR: H	BEAMWIDTH - TRANSVERSE --- DEGREES --- IMPR. DIR: L	BEAMWIDTH - LATERAL --- DEGREES --- IMPR. DIR: L	COMP
** ******************** SUB-TECHNOLOGY: SEMICONDUCTOR SILICON AVALANCHE PHOTODIODE (APD)							
07020 40201 A SBLC	INTERNAL GAIN --- NONE --- IMPR. DIR: H	QUANTUM EFFICIENCY --- NONE --- IMPR. DIR: H	EXCESS NOISE FACTOR --- NONE --- IMPR. DIR: L	DARK CURRENT --- nA --- IMPR. DIR: L	GAIN BANDWIDTH PRODUCT --- GHz --- IMPR. DIR: H	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: GaAs P-I-N PHOTODIODES							
07020 40202 A SBLC	QUANTUM EFFICIENCY --- NONE --- IMPR. DIR: H	DARK CURRENT --- pA --- IMPR. DIR: L	BANDWIDTH --- GHz --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: PHOTOMULTIPLIER TUBE (PMT)							
07020 40203 A SBLC	GAIN --- NONE --- IMPR. DIR: H	QUANTUM EFFICIENCY --- NONE --- IMPR. DIR: H	DARK CURRENT --- nA (NANOAMPS) --- IMPR. DIR: L	EXCESS NOISE --- NONE --- IMPR. DIR: L	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP

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** ******************** SUB-TECHNOLOGY: SPACE BASED LASER COMMUNICATIONS							
09010 20200 A SBLC	LASER TRANSMITTER POWER --- mW (MILLIWATTS) --- IMPR. DIR: H	TRANSMITTING BEAMWIDTH --- uRAD (MICRO-RADIANS) --- IMPR. DIR: L	RECEIVER SENSITIVITY --- dBm (REQUIRED POWER) --- IMPR. DIR: L	RECEIVING APERTURE DIAMETER --- INCHES --- IMPR. DIR: H	ANGULAR POINTING ERROR --- uRAD (MICRO-RADIANS) --- IMPR. DIR: L	BIT ERROR RATE --- ERROR PER 10^6 BITS --- IMPR. DIR: L	SYS PERF
** ******************** SUB-TECHNOLOGY: BEAM COMBINER FOR GaAs LASER DIODES							
13040 A0100 A SBLC	DIODE BEAM QUANTITY --- NONE --- IMPR. DIR: H	THROUGHPUT --- % (PERCENT) --- IMPR. DIR: H	1/e^2 FAR FIELD DIVERGENCE --- uRAD (MIRCO-RADIANS) --- IMPR. DIR: L	OUTPUT BUNDLE DIAMETER --- MM (MILLIMETERS) --- IMPR. DIR: L	POSITIONING ACCURACY --- u (MICRONS) --- IMPR. DIR: L	BEAMWIDTH/DIFFRACTION LIMIT --- NONE --- IMPR. DIR: L	COMP
** ******************** SUB-TECHNOLOGY: TELESCOPE OPTICAL SYSTEM							
13040 A0200 A SBLC	FAR FIELD BEAM SPREAD --- uRAD (MICRO-RADIANS) --- IMPR. DIR: L	POINTING ACCURACY --- uRAD (MICRO-RADIANS) --- IMPR. DIR: L	APERTURE --- INCHES --- IMPR. DIR: H	WAVEFRONT QUALITY --- RMS WAVELENGTH --- IMPR. DIR: L	THROUGHPUT --- % (PERCENT) --- IMPR. DIR: H	--- --- IMPR. DIR:	COMP

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: HIGH-POWER SEMICONDUCTOR DIODE LASER												
06010 10400 A SBLC 27	C	COMMUNICATION RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- KOGANEI-SHI, TOKYO, JAPAN ---- M.SHIKATANI, S. YOSHIKADO, Y. ARIMOTO ---- SEE MEMO	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- KOGANEI-SHI, TOKYO, JAPAN ---- Y.SUZUKI, Y.TAKAHASHI & T.ARUGA ----	NEC & TOSHIBA ---- ---- ---- SEE PAGE#:B016A & B001A	Y P RD U	0.83 ----	030 ----	----	----	----	----	JEY/121 8-01/00 1 01/14/9 0 B015B 01/01/9 1 JA
06010 10400 A SBLC 22	C	MATSUSHITA ELECTRONICS CORP., ELECTRONICS RESEARCH LABORATORY ---- TAKATSUKI, OSAKA 569, JAPAN ---- H.NAITO, M.KUME, K.HAMADA, G.KANO ---- S. MEHERLE HAS VERIFIED THAT THIS ARTCLE PERTAINES TO LASER COM.	MATSUSHITA ELECTRONICS CORP., ELECTRONICS RESEARCH LAB. ---- TAKATSUKI, OSAKA 569, JAPAN ---- H.SHIMIZU ----	---- ---- ----	Y A DT U	0.833 ---- AT 120mW STABLE FUNDAM ENTAL TRANSV ERSE MODE UP TO 120mW	0100 ---- MAXIMU M OUTPUT POWER OF 300mW UNDER CW OPERAT ION WAS ACHIEV ED	051 ----	----	----	----	JEN/VOL 25 #6/0149 5 06/01/8 9 B013A / / JA
06010 10400 A SBLC 16	C	MITSUBISHI ELECTRIC CORP., CENTRAL RESEARCH LABORATORY ---- 1-1,TSUKAGUCHI-HON MACHI, 8-CHOME, AMAGASAKI, HYOGOG 661, JAPAN ---- KEISUKE KOJIMA, KUNIHIKO HARA & K.KYUMA ---- THIS ARTICLE WAS REVEIWED BY S. MEHERLE AND DOES APPLY TO SBLC	---- ---- ----	---- ---- ----	Y A DT U	0.86 ---- LINEWI DTH - 1.5MHz	----	----	----	----	----	JBV/04- 24-89/0 238 04/24/8 9 B008A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
06010 10400 A SBLC 21	B	MITSUBISHI ELECTRIC CORP., CENTRAL RESEARCH LABORATORY ---- TSUKAGUCHI-HONMACHI, 8-1-1, AMAGASAKI, 661, JAPAN ---- M.KUZUMOTO, K.KUBA, S.YAGI ---- ARTCLE VERIFIED BY STEVE MECHERLE AS BEING APPLICABLE FOR LASER COM	MITSUBISHI ELECTRIC CORP., OPTOELECTRONIC & MICROWAVE DEVICES R&D LAB. ---- TOKYO, JAPAN ---- Y. MIHASHI ----	---- ---- ----	Y A DT U	.805 ---- SEE MEMO	1000 ----	.25 ----	----	----	----	JBV/04-24-89/0414 04/24/89 B012B / / JA
06010 10400 A SBLC 10	C	NEC CORP. ---- TOKYO 108, JAPAN ---- ----	TOSHIBA CORP. ---- TOKYO 105, JAPAN ---- ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- TOKYO 105, JAPAN ---- ----	Y A DT U	.830 ----	010 ----	----	----	----	----	JAJ/07-20-89/008 07/20/89 B002A / / JA
06010 10400 A SBLC 11	B	OMRON TATEISI ELECTRONICS CO., CENTRAL R&D LAB. ---- NAGAOKAKYO CITY, KYOTO 617, JAPAN ---- K.IMANAKA, F. SATO, M. SHIMURA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	0.77 ---- COULD BE USED FOR FREE SPACE IF SINGLE SPATIAL MODE	----	----	----	----	----	JAR/08-01-88/076 08/01/88 B003A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
06010 10400 A SBLC 13	B	SONY CORPORATION ---- 4-10-18, TAKANAWA, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	0.77 - 0.84 ----	0500 ----	----	----	----	----	JCJ/01-01-88/0 01 01/01/8 8 B005A / / JA
06010 10400 A SBLC 23	B	SONY CORPORATION ---- 4-10-18, TAKANAWA, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	.77-.8 4 ---- MODEL SLD304	1000 ----	----	----	----	----	JCJ/BRO CHURE/0 01 01/01/8 8 B005B / / JA
06010 10400 A SBLC 24	C	SONY CORPORATION ---- 4-10-18, TAKANAWA, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	.77-.8 4 ---- MODEL SLD302	200 ----	----	----	----	----	JCJ/BRO CHURE/0 01 01/01/8 8 B005C / / JA
06010 10400 A SBLC 19	C	TOKYO INSTITUTE OF TECHNOLOGY, GRADUATE SCHOOL AT NAGATSUTA ---- 4259 NAGATSUTA, MIDORI-KU, YOKOHAMA, KANAGAWA 227, JAPAN ---- M.OHTSU, M.MURATA & M.KOUROGI ---- POTENTIAL APPLICATION TO LASER COM VERIFIED BY TRW EXPERT STEVE MECHERLE	---- ---- ----	---- ---- ----	Y A DT U	.8 ---- USING AlGaAs LASER (CSP TYPE)	----	----	----	----	----	JBV/04-24-89/0 306 04/24/8 9 B011A / / JA

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** ************** SUB-TECHNOLOGY: SEMICONDUCTOR SILICON AVALANCHE PHOTODIODE (APD)												
07020 40201 A SBLC 28	E	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- KOGANEI-SHI, TOKYO, JAPAN ---- M.SHIKATANI, S.YOSHIKADO, Y.SRIMOTO ---- SEE MEMO	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND COMMUNICATIONS ---- KOGANEI-SHI, TOKYO, JAPAN ---- Y.SUZUKI, Y.TAKAHASHI & T.ARUGA ----	---- ---- ----	Y P RD U	---- AN APD IS USED FOR DETECT ING THE UP-LIN K LASER SIGNAL ABOARD THE ETS-VI	----	----	----	----	----	JET/121 8-01/00 8 01/14/9 0 B015C 01/01/9 0 JA
07020 40201 A SBLC 12	C	HAMAMATSU PHOTONICS K.K. ---- 1126, ICHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- PHOTODIODE CATALOG	---- ---- ----	---- ---- ----	N A FP U	0100 ----	070 ---- 70% AT .83 WAVELE NGTH	0.42 ----	07 ----	----	----	JCA/09- 01-89/3 2 09/01/8 9 B004A / / JA
07020 40201 A SBLC 38	D	MINISTRY OF POSTS AND TELECOMMUNICATIONS , RADIO RESEARCH LABORATORIES ---- 4-2-1 NUKUI-KITA-MACHI, KOGANEI, TOKYO 184, JAPAN ---- T.ARUGA & T.IGARASHI ---- SEE MEMO: THREE-AXES DETERMINATION OF SPACECRAFT USING A LASER	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JFC/VOL 13 #5/0473 09/01/7 7 B020C / / JA

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07020 40201 A SBLC 25	C	SHIZUOKA UNIVERSITY, GRADUATE SCHOOL OF ELECTRONIC SCIENCE AND TECHNOLOGY ---- 3-5-1 JOHOKU, HAMAMATSU 432, JAPAN ---- H.KOMOBUCHI ---- ARTCLE VERIFIED BY TRW EXPERT S. MECHERLE AS BEING APLICABLE TO THIS TECHNOLOGY	SHIZUOKA UNIVERSITY, RESEARCH INSTITUTE OF ELECTRONICS ---- 3-5-1 JOHOKU, HAMAMATSU 432, JAPAN ---- M. MORIMOTO & T. ANDO ----	---- ---- ----	Y A DT U	---- SEE MEMO	0.5 ----	----	----	----	----	JAG/VOL 10 #5/0189 05/05/8 9 B014A / / JA
** ************** SUB-TECHNOLOGY: PHOTOMULTIPLIER TUBE (PMT)												
07020 40203 A SBLC 39	D	MINISTRY OF POSTS AND TELECOMMUNICATIONS , RADIO RESEARCH LABORATORIES ---- 4-2-1 NUKUI-KITA-MACHI, KOGANEI, TOKYO 184, JAPAN ---- T.ARUGA & T.IGARASHI ---- SEE MEMO: THREE-AXES ATTITUDE CONTROL OF SPACECRAFT USING A LASER	---- ---- ----	---- ---- ----	Y A DT U	----	0.14 ----	----	----	----	----	JFS/VOL 13 #5/0473 09/01/7 7 B020D / / JA
** ************** SUB-TECHNOLOGY: SPACE BASED LASER COMMUNICATIONS												
09010 20200 A SBLC 28	B	MINISTRY OF POSTS AND TELECOMMUNICATIONS , COMMUNICATIONS RESEARCH LABORATORY ---- KOGANEI-SHI, TOKYO JAPAN ---- M.SHIKATANI, S.YOSHIKADO, Y.ARIMOTO ---- SEE MEMO	MINISTRY OF POSTS AND TELECOMMUNICATIONS , COMMUNICATIONS RESEARCH LABORATORY ---- KOGANEI-SHI, TOKYO, JAPAN ---- Y.SUZUKI, Y.TAKAHASHI & T. ARUGA ----	NEC CORPORATION, SPACE & LASER COMMUNICATION DIVISION ---- 4025 IBEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- ---- SEE SHEETS: B009A, B016, B017	Y P RD U	030 ---- ACCORD ING TO S. MECHER LE THERE WILL BE NO PORTAB LE GROUND STATIO N	30/60 ----	-058 ----	2.95 ---- MAGNIF ICATIO N X15	---- POINTI NG ACCURA CY 2 URAD	001 ----	JEY/121 8-01/01 01/14/9 0 B015A 01/01/9 1 JA

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09010 20200 A SBLC 34	C	MINISTRY OF POSTS AND TELECOMMUNICATIONS , RADIO RESEARCH LABORATORIES ---- KOGANEI-SHI, TOKYO 184 JAPAN ---- T.ARUGA K.ARAKI, R.HAYASHI ---- SEE MEMO: EARTH-TO-GEOSYNCHR ONOUS SATELLITE LASER BEAM TRANSMISSION	MINISTRY OF POSTS AND TELECOMMUNICATIONS , RADIO RESEARCH LABORATORIES ---- KOGANEI-SHI, TOKYO 184, JAPAN ---- T.IWABUCHI, M.TAKAHASHI & S. NAKAMURA ----	---- ---- ----	Y A DT U	3000 ---- GROUND STATIO N ARGON LASER	----	---- RECEIV ER VISSR	----	----	----	JEZ/VOL 24 #1/053 01/01/8 5 B018A / / JA
09010 20200 A SBLC 20	A	MITSUBISHI ELECTRIC CORP., CENTRAL RESEARCH LABORATORY ---- TSUKAGUCHI-HONMACH I, 8-1-1, AMAGASAKI 661, JAPAN ---- M.KUZUMOTO, K.KUBA & S.YAGI ---- ARTCLE VERIFIED BY STEVE MECHERLE FOR LASER COM APLLICATION	MITSUBISHI ELECTRIC CORPORATION, OPTOELECTRONIC & MICROWAVE R&D DEVICE LAB. ---- TOKYO, JAPAN ---- Y.MIHASHI ----	---- ---- ----	Y A DT U	1000 ---- 1 WATT (SEE MEMO)	----	----	----	----	----	JBV/04-24-89/0 414 04/24/8 9 B012A / / JA
09010 20200 A SBLC 14	D	NEC CORPORATION - YOKOHAMA PLANT ---- 4035, IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- ---- The comapny information is not clear whether NEC is involved with Laser Com, further research needed	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JCV/BRO CHURE/0 07 12/10/8 4 B006A / / JA

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09010 20200 A SBLC 35	C	RADIO RESEARCH LABORATORIES ---- KOGANEI-SHI, TOKYO 184, JAPAN ---- T.ARUGA, K.ARAKI, T.IGARASHI, ---- SEE MEMO: EARTH-TO-SPACE LASER TRANSMISSION FOR SPACECRAFT ATTITUDE MEASUREMENT	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- MINATO-KU, TOKYO 105, JAPAN ---- F.IMAI, Y.YAMAMOTO, H.SAKAGAMI ----	---- ---- ----	Y A DT U	03000 ---- 3W FROM GROUND STATIO N ARGON LASER	----	----	019.68 ---- 50cm VIDECO N TELESC OPE	----	----	JEZ/VOL 23 #1/0145 01/01/8 4 B019A 03/17/8 3 JA

SUB-TECHNOLOGY: TELESCOPE OPTICAL SYSTEM

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
13040 A0200 A SBLC 29	C	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- KOGANEI-SHI, TOKYO, JAPAN ---- M.SHIKATANI, S.YOSHIKADO, Y.ARIMOTO ---- SEE MEMO	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- KOGANEI-SHI, TOKYO, JAPAN ---- Y.SUZUKI, Y.TAKAHASHI & T.ARUGA ----	---- ---- ----	Y P RD U	---- ATTITU DE CONTRO L-TWO AXIS GIMBAL	02 ----	02.95 ----	----	----	----	JEY/121 8-01/00 7 01/14/9 0 B015D 01/01/9 1 JA
13040 A0200 A SBLC 37	B	MINISTRY OF POSTS AND TELECOMMUNICATIONS , RADIO RESEARCH LABORATORIES ---- 4-2-1 NUKUI-KITA-MACHI, KOGANEI, TOKYO 184, JAPAN ---- T.ARUGA & T. IGARASHI ---- SEE MEMO: THREE-AXES ATTITUDE DETERMINATION OF SPACECRAFT USING A LASER	---- ---- ----	---- ---- ----	Y A DT U	----	---- 1x10^-2 RAD	9.8 ---- 25cm	----	----	----	JFC/VOL 13 #5/0473 09/01/7 7 B020B / / JA

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** *************** SUB-TECHNOLOGY: HIGH-POWER SEMICONDUCTOR DIODE LASER												
06010 10400 A B015B SBLC 9	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN, (NASDA) ---- TOKYO 105, JAPAN ---- HIDEO OBA ----	---- ---- ----	---- ---- ----	Y P RD U	.850-1 .3 ---- 850NM	----	----	----	----	----	JAJ/07-20-89/0 07 07/20/8 7 B001A / / JA
06010 10400 A B015B SBLC 31	B	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION ---- 4035 IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- M.SHIMIZU, K.SHIRATAMA & Y.OHGUSHI ---- SEE MEMO- POINT AHEAD MECHANISM FOR ETS-VI OPTICAL ISL EXPERIMENT	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- 4-2-1 NUKUI-KITA-MACHI, KONGANEI-SHI, TOKYO 184, JAPAN ---- M.SHIKATANI, Y.ARIMOTO & T.ARUGA ----	---- ---- ----	Y A DT U	0.83 ----	----	----	----	----	----	JEY/121 8-56/00 1 01/14/9 0 B016A / / JA
** *************** SUB-TECHNOLOGY: SPACE BASED LASER COMMUNICATIONS												
09010 20200 A B015A SBLC 18	E	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS & TELECOMMUNICATIONS ---- 4-2-1 NUKUI-KITA-MACHI, KOGANEI, TOKYO 184, JAPAN ---- T.ARUGA, M.SHIKATANI, S.YOSHIKADO ----	COMMUNICATIONS RESEARCH LABOARTORY, MINISTRY OF POSTS & TELECOMMUNICATIONS ---- 4-2-1 NUKUI-KITA-MACHI, KOGANEI, TOKYO 184, JAPAN ---- Y. ARMITO & Y. SUZUKI ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JDZ/E05 .2/0150 10/16/8 9 B010A 01/01/9 3 JA

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09010 20200 A B015A SBLC 17	B	NEC CORPORATION ---- NEC BLDG, 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- PHONE CONVERSATION WITH D. BOETZ REGARDING INTERVIEW WITH JAPANESE ABOUT LASER COM.	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JDX/PHONE CONVERSAT. 10/25/89 B009A 01/01/93 JA
09010 20200 A B015A SBLC 33	B	NEC CORPORATION, SPACE & LASER COMMUNICATION DIVISION ---- 4035 IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- K.SHIRATAMA, T.HAMURO, Y.OHGUSHI, ---- SEE MEMO: FINE POINTING MECHANISM USING MULTILAYER PIEZO-ELECTRIC ACTUATOR FOR OPTICAL ISL EXPERIMEN	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION ---- 4035 IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- M.SHIMIZU ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA), TSUKUBA SPACE CENTER ---- 2-1-1 SENGEN, TSUKUBA-SHI, 305 JAPAN ---- H.ARIKAWA, Y.HISADA & H.ANEGAWA ----	Y A DT U	----	----	----	----	0.75 ----	----	JEY/1218-12/001 01/14/90 B017A / / JA
09010 20200 A B015A SBLC 30	B	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION ---- 4035 IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- M.SHIMIZU, K.SHIRATAMA & Y.OHGUSHI ---- SEE MEMO POINT-AHEAD MECHANISM FOR ETS-VI OPTICAL ISL EXPERIMENT	MINISTRY OF POSTS AND COMMUNICATIONS, COMMUNICATIONS RESEARCH LABORATORY ---- 4-2-1 NUKUI-KITA-MACHI, KONGANEI-SHI, TOKYO 184, JAPAN ---- M.SHIKATANI, Y.ARIMOTO & T.ARUGA ----	---- ---- ----	Y A DT U	----	030 ----	-059.4 ----	----	----	----	JEY/1218-56/001 01/14/90 B016A / / JA

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09010 20200 A B019A SBLC 36	C	RADIO RESEARCH LABORATORIES, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- 4-2-1 NUKUI-KITA-MACHI, KOGANEI, TOKYO 184, JAPAN ---- T.ARUGA & T.IGARASHI ---- SEE MEMO: THREE AXES ATTITUDE DETERMINATION OF SPACECRAFT USING A LASER	---- ---- ----	---- ---- ----	Y A DT U	5000 ---- 5W	0300 ---- 3 RAD	---- 0.2 A/W	09.6 ---- 25cm	----	----	JFC/VOL 13 #5/0473 09/01/7 7 B020A / / JA
09010 20200 A B015A SBLC 15	D	SCIENCE AND TECHNOLOGY AGENCY ---- 2-2-1, KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- HARUMITSU YOSHIMURA ---- SEE MEMO FOR NARATIVE	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JAJ/09- 06-89/0 23 09/08/8 9 B007A / / JA
** *************** SUB-TECHNOLOGY: TELESCOPE OPTICAL SYSTEM												
13040 A0200 A B015D SBLC 32	C	NEC CORPORATION, SPACE & LASER COMMUNICATIONS DIVISION ---- 4035 IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- M.SHIMIZU, K.SHIRATAMA & Y.OHGUSHI ---- SEE MEMO - POINT AHEAD MECHANISIM FOR ET-VI OPTICAL ISL EXPERIMENT	COMMUNICATIONS RESEARCH LABORATORY, MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- 4-2-1 NUKUI-KITA-MACHI, KONGANEI-SHI, TOKYO 184, JAPAN ---- M.SHIKATANI, Y.ARIMOTO & T.ARUGA ----	---- ---- ----	Y A DT U	----	02 ----	---- MAGNIF ICATIO N x15	----	----	----	JEY/121 8-56/00 1 01/14/9 0 B016C / / JA

Record# PAGENO DESCRAPPLC
6 B0000 Nd:YAG LASER

An Nd:YAG (neodymium:yttrium-aluminum-garnet) laser is a cylindrical rod of yttrium-aluminum-garnet doped with neodymium, which is the active medium of this laser. An Nd:YAG laser that is pumped by AlGaAs diodes, is a principle source for a space-based lasercom system, second only to the GaAs diode laser. Because the Nd:YAG laser inherently provides greater power output, it avoids the problems of beam combining. Sufficient power is usually available to close the link. While there is a well-developed electro-optical modulation technique for this laser, the equipment is fairly complex.

The Nd:YAG is the workhorse laser of industry in general nd for the laser crosslink in particular. It can be operated in Q-switched, cavity dump, or mode-locked mode. As such, it can be pulse modulated from low data rate (~0.1 Mbits/sec) to high data rate (~200 Mbits/sec). The overall energy efficiency is low but acceptable and ranges between 1 and 7% depending largely on the type of optical pump source.

Signal modulation by Q-switching involves changing the "Q" (or tuning) of the resonant cavity, which increases the peak power level of the pulses by orders of magnitude. Q-switching is accomplished by either electro-optically modulating the "Q" or by mechanically rotating one mirror of the Fabry-Perot resonator. Cavity dumping, the other means of modulation, is the opening and closing of a cavity port.

The light output from GaAs laser diodes can be used to optically pump the Nd:YAG laser, but while this system does not require beam combining optics, it is subject to problems of uncertainty in the lifetime of the laser diode array, required for pumping, and the concern that the wavelength of the pumping array can shift with age.

2 B0000 HIGH POWER SEMICONDUCTOR LASER DIODE

The laser diode (which is sometimes called a diode laser) is the primary candidate of the four principle sources of laser energy for space communications applications. The laser diode is small, relatively efficient, rugged, available over the wavelength range of 0.8 to 1.7 microns, has long life potential, and can be directly modulated for the transmission of data. The main disadvantage is the limited power output per diode, so that most space applications require the use of diode arrays, that also incorporate beam-combining devices.

Space-based laser communications is a high-power application that requires a coherent device, operating reliably in a stable, diffraction limited beam of 500 to 1000 milliwatts (mW). Short wavelength devices that operate at 0.78 microns have been constructed of layers of gallium arsenide and aluminum gallium arsenide, grown on a substrate of gallium arsenide.

The materials are chemically doped with impurities to give them either an excess of electrons, n-type material, or an excess of

electron vacancies, called holes, which characterize p-type material. When the diode is in normal operation, electrons from the n-type layer and holes from the p-type layer are injected into the active layer between them, where they recombine and emit light. Energy balance is thus maintained through the radiation of light.

The optical index of refraction of the active layer material is larger than the index of refraction of the p-type and n-type materials (the cladding layers) above and below it. The light is therefore trapped in the dielectric waveguide formed by the two cladding layers and the active layer, and propagates within both the active and the cladding layers.

Crystal facets at each end of the diode act as mirrors that cause the light to be substantially amplified as it travels back and forth in the longitudinal direction. Lasing action occurs when enough carriers are injected into the active layer to provide the optical gain needed to overcome the cavity's internal and external losses.

For continuous wave operation at room temperature, low lasing threshold currents are required, which dictate a thin active layer (<0.3 micron). The resulting laser emission pattern is elliptical with typical transverse and lateral beamwidths, at half power, of 40 deg and 10 deg, respectively.

Newer, more efficient diodes embody the separate confinement heterostructure (SCH) single-quantum-well (SQW) which is most common for diode lasers within the power range of 100 mW to 10 W.

For applications requiring beam-forming optics a single element device may be appropriate. Single-mode, index guided lasers, that support only the fundamental transverse mode and the fundamental lateral mode are those in which the light is guided by the refractive index of the various materials.

Another diode structure utilizes phase-locked arrays that provide diffraction limited beams at high output powers. These are best fabricated using the metal-organic chemical vapor deposition (MOCVD) process. Quantum-well lasers, with the double-quantum-well, separate-confinement heterostructure (DQW-SCH) fabricated through MOCVD have provided 700 mW continuous-wave operation at room temperature and power conversion efficiency close to 50 percent.

21 B012B

Recent advances in high power laser diodes (LDs) provide an ideal optical source for pumping solid state lasers. Many researchers have started to study these types of laser, and most of the work has concentrated on end pumped devices, which have the advantage of low thresholds and high slope efficiencies. Although these devices are compact and efficient, they are not suitable for high power devices.

We reported earlier a wide stripe self-aligned bent active (SBA) layer AlGaAs LD with a stripe width of

150 um. This LD produces a cw output power of 1W with a driving current of 2 A at 25 % electrical to optical conversion efficiency. The center wavelength is 805 nm at 20 deg C, and the spectral width is 5 nm. Thus we have developed a side pumping technique for a Nd doped laser with this LD. The pumping geometry is shown schematically.

The LDs were placed on both sides of the YAG rod (2 mm in diameter, 35 mm in length) in alternate positions not facing each other. Furthermore, the LDs on both sides of the rod were set in off centered positions. The internal surfaces of the rod housing and guide holes of the pump light were coated with Au. A transparent and high heat conductive material was filled between housing and rod, which enabled a stress-free efficient cooling of the rod.

The laser cavity consisted of a high reflector with curvature of 30-cm radius and a flat 98% reflecting output coupler located nearly 10 cm away. With 8.4-W pump power, we obtained a stable cw output power of 1W with a symmetrical beam mode. When the axes of the LDs coincided with the center of the rod, a quarter of the pumping power escaped from the guide holes due to the cylindrical lensing effect of the rod, and the mode of the laser became ellipsoidal. The optical conversion and wall plug efficiencies were 12 and 3%, respectively. Taking the cavity loss of nearly 2% into consideration, the present 23.5% slope efficiency of off-centered side pumping seems to have much the same potential as end pumping.

Summarizing: We have demonstrated a stable output power of a cw 1-W YAG laser by off-centered LD side pumping. We believe solid state laser devices with much higher output power can be made with our pumping and cooling system.

31 B016A

SEE PAGE# B015A FOR DETAILS

11 B003A

High Efficiency AlGaAs/GaAs Single-Quantum Well Laser Diode with Short Period (GaInAs) (GaAs) Strained Superlattice Buffer Layer

I . OBJECTIVE

A strained superlattice; buffer layer is proposed to the lattice-matched AlGaAs/GaAs quantum-well heterostructure in order to improve the laser characteristics.

II. BACKGROUND

A lattice-matched (AlGaAs) (GaAs) superlattice buffer layer (SLB) has been used widely in the AlGaAs/GaAs quantum well laser diode to improve the laser quality by the capture of defects. However, the SLB is not effective to an internal stress caused by the difference in the thermal expansion coefficients between the AlGaAs epi-layers and the GaAs substrate when the Al composition in cladding layers is increased ($x > 0.7$). A strained super lattice buffer layer (SSLB), which has been used widely in GaAs/Si hetero-epitaxial system, seems to be effective in such a problem. From these point of view, we have introduced the SSLB followed by the SLB to the AlGaAs/GaAs SQW laser diode grown by MBE.

III. EXPERIMENTS (LASER STRUCTURE)

A 3 um-wide polyimide buried ridge waveguide (PBR) GRIN-SCH-SQW laser structure has been adopted in this experiment. The SSLB and the SLB were composed of 50 pairs of short period super lattice and 5 pairs of respectively, where subscripts indicate the number of monolayer; much attention has been paid to the InGaAs layer growth to avoid the problem of critical layer thickness.

IV. RESULTS (LASER CHARACTERISTICS)
First, root temperature photoluminescence measurements on the laser wafers with both of the SSLB and the SLB, and with the SLB alone have been made. The former showed more than 5 times higher peak intensity than the latter. Figure 2 (not shown here) shows a typical power output versus injected current under cw operation at 25 deg. C in the 675 um-long PBR laser emitting at 770 um without facet coatings. Power output is a almost linear over 50 mW with high differential quantum efficiency of 80%. Very small alpha value of 3 cm^-1 has been observed in such a narrow ridge waveguide laser which is applicable to the practical use. This cavity loss originates mainly in the fluctuation of the ridge width.

V. CONCLUSION

A high quantum yield (nd > 50% even at 3 mm long cavity), a small cavity loss (alpha-3 cm^-1), and a high power operation have been achieved in a 3 um-wide ridge waveguide 770 nm GRIN-SCH-SQW laser diode. These improvements are due to the introduction of strained superlattice buffer layer which relaxes the internal stress.

13 B005A

SEMICONDUCTOR LASER DIODE FEATURES

OPERATING TEMPERATURE	-10 TO +30 DEG C
OPTICAL OUTPUT POWER	500mW
THRESHOLD CURRENT	450
OPERATING CURRENT	1100
OPERATING VOLTAGE	1.9
EMISSION WAVELENGTH	770-840nm
PARALLEL DIVERGENCE	10
PERPENDICULAR DIVERGENCE	28
ASTIGMATISM	200
EMISSION STRIP WIDTH	160Ws
MONITORING OUTPUT CURRENT	0.45

23 B005B
27 B015B

SEE PAGE# B015A FOR DETAILS

22 B013A

Abstract - Long life GaAlAs lasers with 100mW fundamental transverse mode operation have been developed. This excellent degree of operation has been attained by using the non-absorbing mirrors for suppression of mirror degradation and a thin substrate structure for stabilization of the transverse mode. It has been found that under 100mW CW operation at 50 deg. C, degradation is insignificant even after 6000 h.

16 B008A

Summarizing: Mitsubishi Electric Corp. fabricated narrow line width MQW DFB lasers. The minimum line width was 1.5 MHz, which is believed to be the narrowest value ever reported for

AlGaAs/GaAs DFB lasers. This is due to the MQW structure, long cavity, and small confinement factor. The reduction of alpha in MQW DFB lasers compared with bulk DFB lasers was experimentally confirmed. Detailed calculation and other methods of narrowing the line width are also present.

9 B001A

NASDA's Design for Positioning & Communications by 16 Low-Altitude Satellites

Associate Chief Engineer Hideo Oba of the National Space Development Agency of Japan (NASDA) announced a design to build a positioning and communications network system to span the entire globe by having a small satellite ride in the satellite detachment compartment of an "H-II" rocket. This is the result of NASDA's 1988 solicitation of design proposals from within the agency for the effective use of the "H-II" rocket.

This network system determines the position of a moving object with a precision of within several tens of meters, and it allows two-way communications between two moving objects. The principles of position determination and communications are the same as the "NAVNET" method devised by Associate Chief Engineer Koji Yamawaki of NASDA. However, in contrast to NAVNET, which uses two to three Static Satellites, the new system will use 16 satellites that travel in circular orbits at an altitude of approximately 11,000 km. Because the cost of launching is reduced through piggy-back riding, more satellites can be launched. Also, the satellite altitude is lowered to about one third that of the static orbit to increase measurement precision as well as to minimize the time lag of communications.

According to the announcement, the following elemental technologies need to be established to achieve the size and mass of the satellite.

---laser technology for intersatellite communications: high output semiconductor laser in the wavelength bands of 850 nm and 1,300 nm will be needed for tracking and communications between satellites. The semiconductor laser, currently used for optical fiber communications, will be improved to gain more output.

--Roll-type solar battery: the current flexible solar battry still lacks flexibility to be stored in a limited space. The required power will be 5 kW.

--Secondary battery with excellent charge/discharge characteristics: the most promising today is a nickel-hydrogen battery currently under development. Also needed is a reserve power system to be used toward the end of the satellite's life.

--Size and weight reduction of electronic pads: to reduce the total weight of electronic pads to one half the previous satellite, only surface mounted pads must be used. Also, since carbon-fiber-reinforced-plastic (CFRP) materials will be used, a multi-layered substrate with excellent radiation characteristics must be developed.

10 B002A

Test Production of Laser Radar Elements

(NEC) and Toshiba, Ltd. (Toshiba), test produced four Laser radar elemental parts for space rendezvous between two spacecraft. These parts were ordered from these companies by the National Space Development Agency of Japan (NASDA), which has conducted research on rendezvous radar since FY86. NEC, for its part, test-produced an optical system part for transmission and reception and an amplifier for the laser receiver. Toshiba test-produced an angle encoder for the scanning minor.

Laser radar is one of the indispensable technologies for automating rendezvous and docking operations. By using Laser, two approaching spacecraft can more accurately determine their relative positions and relative speeds when the spacecraft are within several tens of radar. The technique is also in development stages in Europe and the U.S. Anticipating an automatic docking of a space technology experiment plane "STEP" with a space shuttle "HOPE," to be launched sometime in the late 90's, NASDA is aiming to establish the basic technology of the radar.

NASDA uses in its experiments a semiconductor laser with an output of approximately 10 mW and a band of wavelength 830nm. This laser is directed toward a corner cube minor mounted on the other spaceplane to track it and to determine the relative position. By controlling the direction of the laser beam with a scanning mirror that is supposed by biaxial gimbal mechanism and manipulated to keep hitting the other crafts mirror, the azimuth of the other spacecraft can be determined from the inclination angle of the gimbal. Also, by modulating the emission Laser and finding the phase lag of the returning beam, the distance to the other craft can be determined.

The angle encoder, which determines the inclination angle of the gimbal, and the highly reliable bearing for the gimbal will be the most important parts to decide the system's precision. Also important is the optical transmission and reception system, which detects the laser illumination and reflected beam. NASDA had the four elemental parts test-produced before the other parts because they need to be small and light weight and to collect experimental data to analyze their anti-environmental properties.

As a result of the test production, there were no problems in the gimbal bearings and the amplifier for received beams, but the need for higher improvements in the angle encoder, and the optical transmission and reception system parts was found. The angle encoder, in which an eddy current potentiometer is used, was found to be affected by environment temperature in that the characteristics of the electronic parts in the sensor head change widely, and the change cannot be corrected by a simple compensation circuit. NASDA has since learned that the desired precision could be secured by incorporating a calibration circuit using a microcomputer. However, since this method will make the device more complicated, NASDA plans to look at other approaches.

As for the optical transmission and reception systems part, the transmission Laser beam was found to widen more than the designated value. The solution to this problem is said to be the

addition of a corrective lens. In April 1989, NASA will begin the environmental tests of the optical transmission and reception system part and of the systems design of a laser radar resets model. The environmental tests will be based on the test criteria for devices to be installed in the "H-II" rocket. The research model will be used for the evaluation as a system, and the test production of the model is scheduled to begin in October 1989.

24 B005C
19 B011A

Narrow line width semiconductor laser are key devices for coherent optical measurement and communication systems. The authors believe that electrical feedback is a promising technique for reducing the line width in a very stable manner. It is proposed that wideband electrical feedback can be realized by using reflected light from a high finesse Fabry-Perot cavity, and sub-kilohertz line widths can be obtained.

3 B0000 SEMICONDUCTOR SILICON AVALANCHE PHOTODIODE (APD)

Photodiodes make use of the photovoltaic effect, which is the generation of a voltage across a P-N junction of a semiconductor when the junction is exposed to light.

The avalanche photodiode is ideal for detecting extremely low level light. It utilizes the avalanche multiplication of photocurrent by means of hole-electrons created by absorbed photons. When the device's reverse-bias voltage nears breakdown level, the hole-electron pairs collide with ions to create additional hole-electron pairs, thus achieving a signal gain.

The APD is similar in construction to the P-I-N photodiode except that the doping of the junction material is altered, which changes the voltage versus current slope characteristic in the vicinity of the reverse-bias avalanche breakdown.

Typical values for avalanche gain usually are less than 200, and unlike the photomultiplier tube this gain cannot be assumed to be noise-free. The optimum APD gain is a function of the anticipated optical background as well as detector dark noise and preamplifier noise. If optimum performance of the detector is desired under all conditions, some form of gain control must be employed to adjust the APD gain as a function of background. In the limit, the avalanche gain goes to unity for high optical backgrounds and the device functions as a P-I-N device.

12 B004A
25 B014A

A charge storage operation in a Si p-n Avalanche Photodiode (APD) was experimentally studied. It was demonstrated that when the APD is pulsed beyond the breakdown voltage, avalanche multiplication gains of more than 10^5 are possible and the count rate of photoinduced output events is proportional to the input light intensity at ultralow-light levels. Moreover in the below breakdown mode, the amount of output signal charge is in proportion to the input light intensity, while the gains are restricted to several tens and below. A slope of photoelectric

conversion curves approaches y=0.5, as a result of self-quenching of the avalanche discharge.

38 B020C

A new method for attiude determination of spacecraft is proposed. The distinctive feature of this method is the ability to determine with high accuracy three elementary angles of the attitude by detection of the electromagnetic wave transmission from a single point. The system consists of a transmitter of a linearly polarized laser beam on the earth (or spacecraft) and receiving equipment on a relevant spacecraft. When the system is used for geosynchronous satellites, the possible accuracies of determination are 10 ^-4 rad or higher for the angles which correspond to roll and pitch, and 10^-2 rad or higher for the angle which corresponds to yaw, with the period of 1 s. The system margin for atmospheric attenuation is estimated to be about 50 dB (midnight) to about 20 dB (midday) on the basis of commercially available components. Consequently, it becomes possible to orient antennas or detectors toward arbitrary points around the laser transmitting point on the earth with a high pointing accuracy.

IMAGING PART

TRANSMISSIVITY	0.3
DETECTOR SENSITIVITY	0.2 A/W
IMAGE ELEMENT SIZE	25x25 um^2
ELEMENTS ARRAY	200x200
FIELD OF VIEW	2.5x10^-2urad
SCANNING SPEED	1 FLAME/S
BANDWIDTH OF AMPLIFIER	1MHz
NOISE EQUIVALENT INPUT POWER	2x10^-16W

28 B015C

SEE PAGE# B015A FOR DETAILS

4 B0000 GaAs P-I-N PHOTODIODES

All photodiodes are two-electrode, radiation-sensitive junctions formed in a semiconductor material in which the reverse current varies with illumination. They are used for the detection of optical power and its conversion to electrical power.

A P-I-N (positive-intrinsic-negative) photodiode is a diode with a large intrinsic region sandwiched between P-doped and N-doped semiconducting regions. (An intrinsic region is a material that conducts in the presence of radiation without the aid of added impurities). Photons absorbed in this region create electron-hole pairs that are then separated by an electric field, thus generating an electric current in a load circuit.

Gallium arsenide (GaAs) or silicon are the two materials most commonly used to construct P-I-N photodiodes.

As explained above, optical energy impinging upon the substrate material creates free electrons and holes and the number of created electron-hole pairs is proportional to the number of incident photons. These free electron-hole pairs are swept into the junction by the field across the device. Upon entering the junction, they result in conduction of charge through the device proportional to the number of electron-hole pairs created. There is no inherent gain in the device. The application of these devices is generally limited by the thermal noise in the electrical circuit around the device, but they do have significantly higher quantum efficiency than the photomultiplier tube.

5 B0000 PHOTOMULTIPLIER TUBE (PMT)

Photomultiplier tubes are closest to the ideal optical detector. They consist of and evacuated envelope (like a vacuum tube) with a photocathode contained within that emits electrons when exposed to light. These electrons are accelerated by a positive electrostatic field and fall upon a metal surface (a dynode) where they emit secondary electrons that are again accelerated to generate more electrons at the next dynode, and so on, until all electrons are finally collected at the anode. This whole arrangement of elements acts as a combination of a simple photocell, with a high-gain amplifier in a self contained unit.

Photomultipliers can typically achieve a gain of >1x10^6, that is for each electron leaving the cathode as many as one million photoelectrons are collected by the anode. This gain is essentially noise-free, resulting in a statistical output identical to the input. Thus, the signal-to-noise ratio is preserved through the tube.

In a ruggedized photomultiplier tube the glass envelope is replaced with a metal and ceramic case, and the internal elements are rigidly supported to withstand space launch environments. Balancing the advantages of noise-free gain are the physical limitations of size and the poor reliability of the high-voltage (5 kV or more) components. Photomultiplier tubes also suffer from typically low quantum efficiencies, as the result of limitations in materials and deposition techniques for the photoactive surfaces, and the inability to efficiently collect all of the generated photoelectrons. Also, each photoelectron follows a slightly different trajectory as it passes from photocathode to the dynodes and finally to the anode. Thus, there is a dispersion of arrival times for the various photoelectrons spawned off the photocathode. Usually, the higher the gain, the greater the number of dynodes; the longer the pathlength, the greater the temporal dispersion. This dispersion, of course, lowers the usable communications bandwidth.

39 B020D

SEE PAGE # B020C FOR DETAILS

1 B0000 SPACE BASED LASER COMMUNICATIONS

Laser communications utilizes light frequencies at about 400,000 GHz for a wavelength of 0.78 micrometers. This carrier frequency is so high above 60 GHz (the RF frequency that is most competitive with lasercom) that the physics and thus the devices of lasercom are totally different from those of the traditional RF system. Lasercom has two major advantages over RF communication systems, much higher antenna gain (due to the narrow beamwidths) and much higher potential bandwidth (usable bandwidth is typically limited to ~0.1f, where f=carrier frequency).

The high antenna gain enables the transmitted power to be more efficiently delivered to the distant receiver, so that the system

may have lower power consumption than RF. Typical telescope size for lasercom is about 8 inches compared to a 10 foot diameter RF antenna. While the narrower beam provides jam-resistance and an inherent low probability of intercept, it requires an active subsystem to provide spatial acquisition and tracking.

Either of two competing detection schemes may be employed. "Direct Detection", also called photo counting, converts the impinging photons into electrons. The phase of the optical carrier is lost and the signal is a result of the optical intensity. Direct detection utilizes either a semiconductor silicon avalanche photodiode (APD), or a semiconductor silicon or GaAs PIN detector, or photomultiplier tube (PMT). Both the APD and PMT offer greater receiver sensitivity than the PIN, as a result of their internal gain. But the poor reliability of the PMT make it an unlikely candidate for a space system.

The other detection scheme, which is called "Coherent Detection", is a receiver process in which a strong local oscillator laser is mixed onto the surface of a (unity gain) detector along with the received field, biasing up the signal at the detector output (heterodyne conversion gain) relative to the additive thermal noise of the detector preamp. This gain is less noisy than the avalanche gain, allowing PMT performance to be achieved with semiconductor detectors for orthogonal signals. However, the coherent detection process preserves the phase of the optical carrier, so that antipodal signals such as phase shift keying (PSK) can be used, resulting in 3dB better performance than a direct detection PMT of the same quantum efficiency.

Using "Homodyne" detection, in which the local oscillator laser is phase locked to the received signal and the IF frequency is zero (baseband), the receiver sensitivity can be improved another 3 dB. Coherent detection receiver sensitivity with PIN diodes can be as much as 10 dB better than direct detection with APDs.

20 B012A

SEE PAGE# B012B FOR DETAILS

26 B015A

OPTICAL INTERSATELLITE LINK EXPERIMENT BETWEEN THE EARTH STATION AND ETS-VI

Communications Research Laboratory (CRL) has been developing an optical satellite communication system and plans to perform basic optical communications experiments using the communication system on board of the Japanese ETS-VI (Engineering Test Satellite-VI) to be launched in 1993. The optical communication payload of ETS-VI, The LCE (Laser Communication Equipment), is under development. The construction of a ground optical facility with a 1.5 meter diameter telescope is almost completed. In the satellite communication experiment, a dual optical communication link will be established and fundamental optical communication experiments will be conducted such as an optical beam pointing/tracking, data transmission, spacecraft attitude precise determination and optical propagation through the atmosphere. This paper describes the outline of the experiment plan and the present status of the system under development.

PAGE# B016A

An offset feed-back type optical beam point-ahead mechanism (PAM) was studied for the application for the laser communication equipment (LCE) of the Engineering Test Satellite VI (ETS-VI) .

For the calibration of the point-ahead angle, a small fraction of the transmitting beam is split back using a corner cube reflector, and is fed into the tracking sensor of an Si four quadrant detector (4QD) to make a precise alignment with the incoming receiving optical signal. In this system a tone frequency is superimposed on each of the transmitting and receiving main communication optical signal. Both of the tone frequencies are detected in the tracking receiver simultaneously and the receiving beam is adjusted to point the center of the 4QD sensor using a fine-pointing mechanism. The transmitting beam is controlled to point a direction with an offset equivalent to the point-ahead angle determined by almanac data, against the receiving beam using a closed feed-back technique.

A small lever-type mirror deflecting--mechanism with a maximum deflection angle of 3.5 mrad and a resolution less than 3 urad was developed for the PAM using a multi-layer piezo-electric actuator. The beam angle fluctuation was less than +-15 urad in the point ahead feed-back control experiment, and the PAM was shown to be suitable for the LCE point-ahead requirements, since the fluctuation would be suppressed to 1/15 by the transmitting telescope with x15 magnification

PAGE# B017A

A new type of the fine pointing mechanism (FPM) was examined as part of the optical ISL studies conducted by NASDA. Compact piezo-electric mirror deflecting mechanism (MDM), having a very high resolution (less than 3 urad) was fabricated, and the performance of the MDM was evaluated aiming for application in the ISL optical FPM.

The fundamental performance of the fine pointing assembly (FPA) in optical ISL with the multi-layered piezo-electric MDM was Confirmed sufficient for optical ISL having pointing error by disturbance (+- 0.75 urad) and pointing angle (+- 720 urad) .

It was confirmed that the examined FPM is suitable for the fine pointing of optical ISL, by combining appropriately designed optics and coarse pointing assembly (CPA), through a preliminary system design

17 B009A

DATE: 10-25-89

Dan Boetz, TRW Laser Communications Expert, Had just returned from a CLEO conference in Florida with information pertaining to what the Japanese are doing in the field of Space Based Laser Communications. In the phone conversation I had with Dan on 10-25 89, he indicated that the Japanese were going to experiment

with free space laser communications on the ETS-VI mission . The scheduled launch date is in the year 1993. ET-VI will weigh 20 KG and will be in a LEO orbit. The satellite will carry an AR laser having a wavelength of .83 microns as determined by the Japanese government. The laser was built by NEC and future lasers will be developed by this company.

33 B017A

SEE PAGE# B015A FOR DETAILS

30 B016A

SEE PAGE # B015A FOR DETAILS

34 B018A

We have succeeded in the experiment of laser beam transmission from a ground station to a geosynchronous satellite. Results of this experiment from the geosynchronous satellite indicate: (1) orbit prediction correction of microwave ranging data is possible using some optical tracking data of one night; the accuracy is within 40 urad for the subsequent 1-2 days and 0.1-0.2 mrad for a longer period 1-2 months; (2) earth-to-geosynchronous satellite laser beam transmission is possible with the same accuracy as the orbit prediction; (3) the 30-urad laser spot image could be very useful for accurate absolute position calibration and attitude determination. The technique used in this work should be applicable to other geosynchronous satellites that include VISSR detectors.

35 B019A

A method of attitude determination of spacecraft by means of an optical technique is presented in which the laser beam is transmitted from a ground station and detected by a TV camera on a satellite. The principal of determining three attitude parameters using the sequential multiple spot images of the laser beam transmitter appearing in the TV camera's image plane is discussed briefly. Experiments of attitude determination by this method have been conducted, where a TV camera on board the Japanese Engineering Test Satellite-3 (ETS-3) and a ground-based optical station are used. In the experiments, argon laser transmission from the earth to space and satellite observation by the optical system were done simultaneously. The attitude of the satellite was determined with high accuracy for some orbits, which permitted us to evaluate the three axis attitude control system and some attitude control experiments of the satellite.

36 B020A

SEE PAGE# B020C FOR DETAILS

14 B006A

SATELLITE COMMUNICATIONS

Microwave communications
- o Microwave and Satellite Communications Division
- o 1st Microwave Communications Systems Division
- o 2nd Microwave Communications Systems Division
- o Space and Laser Communications Development Division

First there was the radio, then there was microwave. Since the beginning of the fifties, microwave radio relay systems have been facilitating inter-city communications throughout the world. NEC pioneered in this development of microwave, and today, with a 90 percent share of the Japanese domestic market and microwave stations in more than 74 countries around the globe, NEC's microwave communications technology ranks top in the world. This new technology includes line-of-sight microwave communications system and trans-horizon communications system.

New products continue to result from our long experience in radio communications. For instance, for remote areas or for places with no commercial power supply, NEC has developed the 2GHz, 4GHz and up to 8GHz microwave radio relay systems that operate by thermoelectric generators, solar cells or primary cells. Or our new fully solid-state 1800 CH microwave communications equipment for trunk route use. NEC microwave equipment now spans 1,681,181 RF-CH kilometers, more than forty-two times the earth's circumference.

Immediate Development Goals

* Accommodation of larger transmission capacity per radio frequency

* High reliability at minimum maintenance cost

* Creation of new radio frequencies

* Total system economy

Main Products

* FDM Microwave Equipment
  Heterodyne repeating systems
  Baseband repeating systems
  Direct repeating systems

* PCM Microwave Equipment
  Regenerator repeating systems
  IF repeating system

* Trans-Horizon Equipment

* Millimeter Wave Equipment

* Optical communications Equipment
  Communication subsystems for satellites

15 B007A

Summarizing: Misubishi Electric Corp. fabricated narrow linewidth mqw DFB lasers. The minimum linewidth was 1.5 MHz, which is believed to be the narrowest value ever reported for AlGaAs/GaAs DFB lasers. This is due to the MQW structure, long cavity, and small confinement factor. The reduction of alpha in MQW DFB lasers compared with bulk DFB lasers was experimentally confirmed. Detailed calculation and other methods of narrowing the linewidth are also present.

18 B010A

A system for basic space optical communication experiments using a Japanese geostationary satellite ETS-VI which will be launched in 1992 and a ground station, is presented.

The system is designed to conduct several fundamental experiments for future inter-satellite optical communication. These are, 1) high-precision tracking, 2) dual-link optical communication, 3) high accuracy attitude measurement, 4) point-ahead angle verification test, 5) laser beam propagation and 6) optical device tests in space. The experiments are done using a link between ground and geostationary orbit.

For the dual-link optical communication experiment, a LD is used for the down-link while an argon laser is used for the up-link. The LCE (Laser Communication Equipment) on board

the ETS-VI satellite includes a two-axis gimbaled mirror, telescope, fine pointing assembly, point-ahead assembly, LD/modulator, APD/de-modulator and onboard- computer.

DOWN LINK = 0.83um
UP LINK = 0.51um

7 B0000 BEAM COMBINER FOR GaAs LASER DIODES

Power-combining technology for GaAs laser diodes will provide a practical way to increase the power and data rates available from laser diodes. Coherent combining using integrated optics technology promises dramatic improvements in diode laser brightness by increasing power in the beam while decreasing the beam divergence.

While it is a rather cumbersome approach, the beam combiner can combine a moderate number of diode beams with high efficiency and high optical quality. Conceptually, an 18-diode laser beam combiner consists of an afocal telescope used as a beam minifier of 2 rings of diodes where the outer one has 11 and the inner has seven diodes. Before illuminating the primary mirror of the combiner, each diode output meets first a wide angle microscope objective consisting of many anamorphic lenses. Here the laser beam is transformed into a nearly circular beam without truncating much of the diode laser output. The combiner uses both primary and secondary paraboloid mirrors. The combined beam emerges through an opening in the center of the primary mirror.

Two advantages of the beam combiner approach are to relax the pointing accuracy requirement by projecting a broader beam, and to increase the reliability of the transmitter by incorporating 18 diodes into the device, so that individual diode failures lead to graceful degradation rather than a system failure.

8 B0000 TELESCOPE OPTICAL SYSTEM

RF and laser communication systems both utilize an antenna to direct the transmitted energy to the receiver and to focus the receiving detector on the transmit terminal. While RF antennas can be anything from a simple dipole (such a TV antenna) to a high-gain Cassegranian dish (common at satellite ground stations), the laser system (which transmits optical power) uses a conventional design telescope as an antenna. The size and geometry of this telescope is dictated by the wavelength and system requirements.

In a typical spaceborne optical communication telescope, coarse system pointing may be achieved by gimballing the entire telescope barrel. Thermal hardware enables the telescope to maintain diffraction limited performance in the presence of space thermal environments.

Due to the extremely short wavelengths involved, the efficiency of optical antenna usually is limited by the ability to control the physical contour of the individual reflecting or transmitting surfaces. For RF wavelengths of several millimeters controlling physical tolerances of the antenna surfaces to less than 1 percent of the wavelength usually presents no great difficulty. However for optical systems with wavelengths on the order of 1 micron, mechanical tolerances would be extremely tight. So much so, in fact, that the amount of wavefront phase error across the transmitting antenna is the primary limitation of telescope performance, and optical telescopes are evaluated on the basis of their wavefront quality (the relative number of waves of phase

error).

37 B020B

SEE PAGE# B020C FOR DETAILS

29 B015D

OPTICAL INTERSATELLITE LINK EXPERIMENT BETWEEN THE EARTH STATION AND ETS-VI

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32 B016C

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SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX C

SYNTHETIC APERTURE RADAR FOR SPACE-BASED REMOTE SENSING (SARSBRS)

1407010A08 - SARSBRS - SYSTEM PERFORMANCE

PHASED ARRAY ANTENNAS, CORPORATE FEED:

1407030A08 - ACTIVE ARRAY DESIGN

1407030A09 - PASSIVE ARRAY DESIGN

PHASED ARRAY ANTENNA, LENS FEED:

1407030A10 - ACTIVE ARRAY DESIGN

1407030A11 - PASSIVE ARRAY DESIGN

1407030A12 - REFLECTOR ANTENNA, MECHANICAL SCAN

1407050A00 - REAL-TIME SIGNAL PROCESSOR

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: S.A.R FOR SPACE BASED REMOTE SENSING

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: SYNTHETIC APERTURE (OR ARRAY) RADAR SYSTEM								
14070 10A08	A	BL		B	C0000		Y	
14070 10A08	A	JA	D	S	C002A	C001A	Y	ELECTROTECHNICAL LABORATORY
14070 10A08	A	JA	E	P	C004A	P	Y	INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE
14070 10A08	A	JA	E	S	C014A	C001A	Y	JAPAN GOVERNMENT
14070 10A08	A	JA	E	S	C007A	C001A	Y	JAPAN TECHNOLOGY TRADE SHOW 4-15-87
14070 10A08	A	JA	D	S	C016A	C001A	Y	MITSUBISHI ELECTRIC CORPORATION
14070 10A08	A	JA	D	S	C012A	C001A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14070 10A08	A	JA	D	S	C003B	C001A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN(NASDA)
14070 10A08	A	JA	E	S	C005A	C001A	Y	NEC CORPORATION
14070 10A08	A	JA	D	S	C009A	C001A	Y	NEC CORPORATION
14070 10A08	A	JA	D	S	C010A	C001A	Y	NEC CORPORATION
14070 10A08	A	JA	D	S	C015A	C001A	Y	NEC CORPORATION
14070 10A08	A	JA	D	P	C001A	P	Y	SCIENCE AND TECHNOLOGY AGENCY (STA)
14070 10A08	A	JA	E	S	C013A	C001A	Y	UNKNOWN

Page No. 2
01/04/93

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: S.A.R FOR SPACE BASED REMOTE SENSING

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, CORPORATE FEED, ACTIVE								
14070 30A08	A	BL		B	C0000		Y	
14070 30A08	A	JA	D	P	C011A	P	Y	MITSUBISHI ELECTRIC CORPORATION
** *** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, CORPORATE FEED, PASSIVE								
14070 30A09	A	BL		B	C0000		Y	
14070 30A09	A	JA	D	P	C016B	P	Y	MITSUBISHI ELECTRIC CORPORATION
** *** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, LENS FEED, ACTIVE								
14070 30A10	A	BL		B	C0000		Y	
** *** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, LENS FEED, PASSIVE								
14070 30A11	A	BL		B	C0000		Y	
** *** SUB-TECHNOLOGY: REFLECTOR ANTENNA, MECHANICAL SCAN								
14070 30A12	A	BL		B	C0000		Y	
** *** SUB-TECHNOLOGY: REAL-TIME SIGNAL PROCESSOR								
14070 50A00	A	BL		B	C0000		Y	
14070 50A00	A	JA	E	P	C008A	P	Y	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENGY OF JAPAN (NASDA)
14070 50A00	A	JA	E	S	C003A	C001B	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14070 50A00	A	JA	E	P	C001B	P	Y	SCIENCE AND TECHNOLOGY AGENCY

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: S.A.R FOR SPACE BASED REMOTE SENSING

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
14070 50A00	A	JA	D	P	C006A	P	Y	TOSHIBA CORP., ELECTRONICS AND TELECOMMUNICATIONS GROUP

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: S.A.R. FOR SPACE BASED REMOTE SENSING

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: SYNTHETIC APERTURE (OR ARRAY) RADAR SYSTEM							
14070 10A08 A SARSB RS	RESOLUTION - AZIMUTH (da) --- FEET --- IMPR. DIR: L	RESOLUTION - RANGE (dr) --- FEET --- IMPR. DIR: L	SWATH WIDTH --- NM (NAUTICAL MILES) --- IMPR. DIR: H	AREA SEARCH RATE --- SQ NM/SEC --- IMPR. DIR: H	IMAGE CONTRAST --- dB --- IMPR. DIR: L	AGILITY --- DEGREES/SEC --- IMPR. DIR: H	SYS PERF
** ******************** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, CORPORATE FEED, ACTIVE							
14070 30A08 A SARSB RS	GAIN --- dB --- IMPR. DIR: H	WEIGHT PER UNIT AREA --- Kg/M^2 --- IMPR. DIR: L	DIMENSIONAL TOLERANCE --- MM --- IMPR. DIR: L	EFFICIENCY --- PERCENT --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, CORPORATE FEED, PASSIVE							
14070 30A09 A SARSB RS	GAIN --- dB --- IMPR. DIR: H	WEIGHT PER UNIT AREA --- Kg/M^2 --- IMPR. DIR: L	DIMENSIONAL TOLERANCE --- MM --- IMPR. DIR: L	EFFICIENCY --- PERCENT --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, LENS FEED, ACTIVE							
14070 30A10 A SARSB RS	GAIN --- dB --- IMPR. DIR: H	WEIGHT PER UNIT AREA --- Kg/M^2 --- IMPR. DIR: L	DIMENSIONAL TOLERANCE --- MM --- IMPR. DIR: L	EFFICIENCY --- PERCENT --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: S.A.R. FOR SPACE BASED REMOTE SENSING

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, LENS FEED, PASSIVE							
14070 30A11 A SARSB RS	GAIN --- dB --- IMPR. DIR: H	WEIGHT PER UNIT AREA --- Kg/M^2 --- IMPR. DIR: L	DIMENSIONAL TOLERANCE --- MM --- IMPR. DIR: L	EFFICIENCY --- PERCENT --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: REFLECTOR ANTENNA, MECHANICAL SCAN							
14070 30A12 A SARSB RS	GAIN --- dB --- IMPR. DIR: H	WEIGHT PER UNIT AREA --- Kg/M^2 --- IMPR. DIR: L	DIMENSIONAL TOLERANCE --- MM --- IMPR. DIR: L	EFFICIENCY --- PERCENT --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: REAL-TIME SIGNAL PROCESSOR							
14070 50A00 A SARSB RS	STORAGE CAPACITY --- BITS --- IMPR. DIR: H	THROUGHPUT --- MEGABITS/SECOND --- IMPR. DIR: H	POWER REQUIREMENT --- WATTS --- IMPR. DIR: L	FAST FOURIER TRANSFORM SPEED --- MICROSECONDS/ 4K PT --- IMPR. DIR: L	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: S.A.R. FOR SPACE BASED REMOTE SENSING

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: SYNTHETIC APERTURE (OR ARRAY) RADAR SYSTEM												
14070 10A08 A SARSB RS 13	E	INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE ---- YOSHINODAI, SAGAMIHARA-SHI, KANAGAWA 229, JAPAN ---- HARUTO HIROSAWA & YUKIHIKO MATSUZAKA ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JBN/VOL 26 #5/0697 09/01/8 8 C004A / / JA
14070 1CA08 A SARSB RS 9	D	SCIENCE AND TECHNOLOGY AGENCY (STA) ---- 2-2-1 KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- UNKNOWN ----	MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY (MITI) ---- 1-3-1 KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- UNKNOWN ----	COMPANIES INVOLVED-NEC, MITSUBISHI, ELECTROTECHNICAL LABORATORY ---- ---- ---- PAGE#:C002A, C005A, C009A, C015A, C016A	Y A RD U	059.05 ---- 18m (IN 3 LOOKS)	059.05 ---- 18m	040.50 ----	----	----	----	JAA/VOL 3 #13/08 / / C001A / / JA
** *************** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, CORPORATE FEED, ACTIVE												
14070 30A08 A SARSB RS 30	D	MITSUBISHI ELECTRIC CORPORATION ---- MARUNOUCHI, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	>= 33.7 ----	<=559 ---- DIMENS ION = 11.92x 2.06x0 .02 m	----	----	----	----	JCL/02- 01-86/0 21 02/01/8 6 C011A / / JA
** *************** SUB-TECHNOLOGY: PHASED ARRAY ANTENNA, CORPORATE FEED, PASSIVE												
14070 30A09 A SARSB RS 26	D	MITSUBISHI ELECTRIC CORPORATION ---- JAPAN ---- N.IMURA, A.AKAISHI & M.ONO ---- SEE MEMO: A R&D MODEL OF SAR ANTENNA	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- JAPAN ---- Y.HISADA & Y.ITOH ----	---- ---- ----	Y A DT U	26.1 ---- TEST RESULT S-33.8 WAS PREDIC TED	----	----	----	----	----	JFA/8-2 7-84/57 3 08/27/8 4 C016B / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: S.A.R. FOR SPACE BASED REMOTE SENSING

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: REAL-TIME SIGNAL PROCESSOR												
14070 50A00 A SARSB RS 17	E	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENGY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JBO/VOL III/141 3 08/01/8 6 C008A 11/03/8 3 JA
14070 50A00 A SARSB RS 8	E	SCIENCE AND TECHNOLOGY AGENCY ---- 2-2-1 KASUMIGASEKI, CHYODA-KU, TOKYO 100, JAPAN ---- UNKNOWN ----	MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY (MITI) ---- 1-3-1 KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- UNKNOWN ----	---- ---- ----	Y A DT U	----	---- DATA TRANSF ER RATE	----	---- SPEED NOT INDICA TED	----	----	JAA/VOL 3 #13/009 01/13/8 9 C001B / / JA
14070 50A00 A SARSB RS 15	D	TOSHIBA CORP., ELECTRONICS AND TELECOMMUNICATIONS GROUP ---- KAWASAKI, JAPAN ---- M.KUBO, K. HORIGUCHI, Y. KUNIYASU ----	TOSHIBA CORP., ELECTRONICS AND TELECOMMUNICATIONS GROUP ---- KAWASAKI, JAPAN ---- S.HORII, E.OSAKI, Y.OSHIMA, K.HIROSHMA ----	TOSHIBA CORP., MEDICAL ENGINEERING LABORATORY ---- OHTAWARA, JAPAN ---- N. KAKAYAMA, K. SUZUKI ----	Y P RD U	----	---- SEE MEMO	----	02000 ----	----	----	JBO/VOL III/014 33 08/01/8 6 C006A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: S.A.R FOR SPACE BASED REMOTE SENSING

** *************** SUB-TECHNOLOGY: SYNTHETIC APERTURE (OR ARRAY) RADAR SYSTEM

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14070 10A08 A C001A SARSB RS 10	D	ELECTROTECHNICAL LABORATORY ---- 1-1-4 UMEZONO, TSUKUBA-SHI, IBARAKI 305, JAPAN ---- K.KOMIYAMA ----	---- ---- ----	---- ---- ----	Y P RD U	058 ---- APPROX MEASUREMENT 18 m	058 ---- SAME AS ABOVE	----	----	----	----	JBM/VOL 25 #7/0468 03/30/89 C002A 01/01/92 JA
14070 10A08 A C001A SARSB RS 23	E	JAPAN GOVERNMENT ---- ---- ---- EDITORIALTHAT APPEARED IN THE JAPAN TIMES 9-19-89 PROMOTING JAPANESE REMOTE SENSING	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JBE/261320Z 9-89/001 09/26/89 C014A / / JA
14070 10A08 A C001A SARSB RS 16	E	JAPAN TECHNOLOGY TRADE SHOW 4-15-87 ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JAU/MSG 3944/001 04/23/87 C007A 01/01/91 JA
14070 10A08 A C001A SARSB RS 25	D	MITSUBISHI ELECTRIC CORPORATION ---- JAPAN ---- N. IMURA, A.AKAISHI & M.ONO ---- SEE MEMO: A R&D MODEL OF SAR ANTENNA	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- JAPAN ---- Y.HISADA & Y.ITOH ----	---- ---- ----	Y A DT U	68.58 ---- 25x25m	68.58 ----	40.5 ----	----	----	----	JFA/8-27-84/573 08/27/84 C016A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: S.A.R FOR SPACE BASED REMOTE SENSING

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14070 10A08 A C001A SARSB RS 21	D	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1. HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- YUJI MIYACHI & YASUSHI HORIKAWA ----	NASDA LOS ANGELES OFFICE ---- 300 SOUTH GRAND AVENUE, SUITE 2760, LOS ANGELES,CA 90071 ---- YOSHIKAZU KAMIYA ----	---- ---- ----	Y P RD U	059 APPROX . ---- ERS-1	059 APPROX . ----	040.5 APPROX ----	----	----	----	JBT/VOL III/162 3 / / C012A 01/01/9 1 JA
14070 10A08 A C001A SARSB RS :2	D	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN(NASDA) ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	----	----	040.5 ----	----	----	----	JAJ/01- 27-89/0 151 01/27/8 9 C003B 01/01/9 2 JA
14070 10A08 A C001A SARSB RS 14	E	NEC CORPORATION ---- TOKYO, JAPAN ---- K.TANAKA, H.SHINOHARA, H. NISHINO ---- SEE B & C FOR OTHER PARTICIPANTS	NEC CORPORATION ---- TOKYO, JAPAN ---- H. KASHIHARA, K. NISHIKAWA ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- TSUKUBA SPACE CENTER, IBARAKI, JAPAN ---- Y.HISADA, Y.ITOH ----	Y A DT U	----	----	----	----	----	----	JBO/VOL . II/0119 5 08/01/8 6 C005A / / JA
:4070 10A08 A C001A SARSB RS 18	D	NEC CORPORATION ---- TOKYO, JAPAN ---- M.FUKAI, K. NISHIKAWA, I.IZUMI, T.TSUJI, ----	NEC CORPORATION ---- TOKYO, JAPAN ---- H:KONDO, H.KASHIHARA, H.NISHINO,K.TANAKA ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- IBARAKI, JAPAN ---- Y. HISHADA & Y. ITOH ----	Y A DT U	---- SEE MEMO	---- SEE MEMO	040.5 ---- 75 KM	----	----	----	JBO/VOL II/0118 7 08/01/8 6 C009A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TPW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: S.A.R FOR SPACE BASED REMOTE SENSING

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14070 10A08 A C001A SARSB RS 19	D	NEC CORPORATION ---- 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NOBUHIKO MORI & SHUNJI MURAI ---- NOTE - S. MURAI ON ASSIGNMENT TO TOKYO UNIVERSITY, YOKOHAMA 226, JAPAN	SUMITOMO METAL MINING CO., LTD ---- 1-3 OHTEMACHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- HIDETOSHI TAKAOKA ----	EARTH RESOURCES SATELLITE DATA ANALYSIS CENTER ---- ?, JAPAN ---- KUNISHIGE TONOIKE & JIRO KOMAI ----	Y A DT U	59.05 ---- 18m	59.05 ----	40.5 ----	----	----	----	JAJ/01-26-89/0 69 01/26/8 9 C010A / / JA
14070 10A08 A C001A SARSB RS 24	D	NEC CORPORATION ---- TOKYO, JAPAN ---- M.FUKAI, K.TANAKA, H.KASHIHARA ---- SEE MEMO: SOME TEST RESULTS OF SAR TRASMITTER & RECEIVER	NEC CORPORATION ---- TOKYO, JAPAN ---- I.IZUMI, E.KADOTA & E.TAKANO ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA), TSUKUBA SPACE CENTER ---- IBARAKI, JAPAN ---- Y.ITOH & Y.HISADA ----	Y A DT U	68.58 ---- 25mx25 m	68.58 ----	40.5 ----	----	----	----	JFA/8-27-84/02 1 08/27/8 4 C015A / / JA
14070 10A08 A C001A SARSB RS 22	E	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHORNOT IDENTIFIED IN THIS ARTICLE	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JDE/10-01-89/0 28 10/01/8 9 C013A 01/01/9 2 JA

** ############### SUB-TECHNOLOGY: REAL-TIME SIGNAL PROCESSOR

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14070 50A00 A C001B SARSB RS 11	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JAJ/01-27-89/0 151 01/27/8 9 C003A 01/01/8 9 JA

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1 C0000

SYNTHETIC APERTURE RADAR SYSTEM

Space-based remote sensing may use radar sensors for a variety of applications including, intelligence or military reconnaissance, earth resources, ground mapping, scientific studies and others. For most applications resolution (the ability to resolve closely spaced individual features of the terrain or target) is the key measure of system performance. Resolution is usually expressed in terms of a range component, or distance (dr) and an azimuth component (da), which comprise the sides of a resolution cell or a "pixel".

The resolution required is a function of the type of target as well as the system mission. The two examples below illustrate the differences for each mission for two diverse targets.

Targets	Detection	Genl Ident	Precise Ident	Description
Rockets	3 Feet	2 Feet	6 inches	2 inches
Harbors	100 Feet	50 Feet	20 Feet	10 Feet

As a general rule the resolution distance, or spot, should be somewhere between 1/5th and 1/20th of the major dimension of the smallest object to be recognized. Also, the amount of signal processing required is inversely proportional to the square of the resolution distance (for a square pixel). A reduction to 50% will quadruple the processing. Range resolution is directly related to pulsewidth with a resolution of about 500 feet per microsecond. Minimum pulsewidth is limited by the bandwidth of frequencies passed by the receiver and transmitter, requiring a bandwidth on the order of 100 megahertz for a 0.01 microsecond pulse width. Depending upon the frequency, bandwidth may be between 3 and 10% of the frequency, beyond which the system becomes prohibitively expensive to design and build. The average transmitted power at very narrow pulsewidths may be increased by pulse compression ratios of 1000:1.

Azimuth resolution is related to the range and the wavelength divided by the antenna length. At any range, resolution can be increased by using shorter wavelengths (subject to atmospheric attenuation) or longer antennas, which are limited by the size of the space vehicle.

Fine resolution at long ranges can be obtained however, by creating an antenna of the desired length synthetically. A synthetic aperture radar utilizes the forward motion of a small antenna to simulate the equivalent of an array antenna that is thousands of feet long, and the beamwidth is about half that of a real array that long. The outputs of the array are synthesized in a signal processor from the series of returns received by the real antenna over periods of up to several seconds or more. The signal processor analyzes the frequency shift (doppler) which in turn is the rate of change of phase. This doppler effect is the result of relative motion between the antenna and target along the flight-path direction. This spectral signal processing may be done either optically or digitally.

Because the current optical process uses a film transfer step and bulky equipment, it must be done later on, the ground. Digital processing is possible in real or near-real time and can incorporate instant changes in scale, resolution and format.

The principal system elements consist of the antenna array, transmitter, receiver, and the very complex signal processor.

10 C002A

The Japanese earth resource satellite (JERS-1), which will be launched in 1992, is to load an L-band SAR whose specifications are shown below.

JERS-1 SPECIFICATIONS

Frequency	1275 MHz
Polarization	H-H
Off Nadir-Angle	35 deg
Pulse Width	35 us
Beam Width	1 deg
Resolution:	
Range	18m
Azimuth	18m

A delayed-action reflector is proposed for external radar calibration. Accurate calibration is expected by the reduction of the back-scattering from the background terrain and a smaller reflector can be used, so that the radar state is not influenced during the imaging of the terrain with calibration.

13 C004A

Calibration of A Cross-Polarized SAR Image Using Dihedral Corner Reflectors

Abstract --A X-band cross-polarized SAR image taken from an aircraft has been calibrated using 45 deg. inclined dihedral corner reflectors with an aperture dimension of 15cm x 25cm. The experimental procedure, the characteristics or the corner reflector, and the result of the experiment are described.

I. INTRODUCTION

Trihedral corner reflectors are widely used for calibration of SAR images, but they generate only like-polarized radar returns. Trihedral corner reflectors do not work as a reflector for cross-polarized SAR. Ulaby and Brunfeldt have developed an active-type reflector that can be used for calibration of cross- as well as like-polarized SAR images; but there have been no reports on attempts to make calibration of cross-polarized SAR images using a passive reflectors.

This paper presents our experiment, which used dihedral corner reflectors to calibrate a cross-polarized SAR image. The experiment was carried out during an airborne SAR campaign (called the SAR-580 Experiment conducted by the National Space Development Agency of Japan in 1983 using the Conrvair-580 aircraft of the Canada Center for Remote Sensing .

SUMMARY

We have made absolute calibration of a cross-polarized SAR image using dihedral corner reflector. We put four reflectors of the same size in a field. giving them different elevation angles such that at least two of them generate returns on a SAR image. By this arrangement the effects of shift of a flight path from a predetermined one and heading variations due to cross-winds were minimized. The results of the experiment was satisfactory. The uncertainty in o^0 estimation has been estimated to be +1.1/-1.2 dB in a local area surrounding

the reflectors. The purpose of this experiment was to examine the feasibility of the dihedral corner reflector, so we put only one set of corner reflectors in this experiment. When we apply this method for actual SAR observations in the future, it will be better to arrange a number of arrays (sets of reflectors) with an extended range of radar cross section.

23 C014A

SUBJECT: JAPAN TIMES EDITORIAL PROMOTES JAPANESE REMOTE SENSING PROGRAMS IN FUTURE INTERNATIONAL GLOBAL CHANCE STUDIES.

1 . SUMMARY: THE LEAD EDITORIAL IN THE SEPTEMBER 19, 1989, ISSUE OF THE ENGLISH LANGUAGE JAPAN TIMES PROPOSES AN ACTIVE ROLE FOR JAPANESE DATA MANAGEMENT AND SATELLITE REMOTE SENSING IN FUTURE INTERNATIONAL GLOBAL CHANCE STUDIES. THE TIMELY AND UNUSUALLY DETAILED REVIEW REFLECTS A JAPANESE FOCUS ON GLOBAL ENVIRONMENTAL ISSUES, AND MAY INDICATE AN INTENT TO ASSUME A GREATER ROLE IN RELATED INTERNATIONAL COOPERATIVE SPACE APPLICATIONS. SUCH POTENTIAL INTENT SHOULD BE OF INTEREST TO NASA AND NOAA'S NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE (NOAA/NESDIS), THE TWO PRIMARY USE PLAYERS IN SATELLITE REMOTE SENSING AND DATA MANAGEMENT.

2. THE LEAD EDITORIAL IN THE SEPTEMBER 19, 1989, ISSUE OF THE JAPAN TIMES STATES THE NEED TO STUDY THE EARTH "AS AN INTEGRATED WHOLE," AND DESCRIBES NASA 'S MISSION TO PLANET EARTH INITIATIVE AS THE PROJECT THAT COULD EXAMINE THE PLANET "IN A SY STEMATIC AND COMPREHENSIVE WAY." THE EDITORIAL ASSERTS THAT STUDY OF PHENOMENA SUCH AS GLOBAL WARMING, OZONE DEPLETION AND "MATTERS RELATED TO THE SEAS AND THE DESERTS" WOULD BE ASSISTED BY REMOTE SENSING SATELLITES AND INSTRUMENTS BUILT IN JAPAN "AND IN EUROPE, AS WELL AS IN THE U.S." THE EDITORIAL REFERS TO EXPECTED ADVANCES IN SUPERCOMPUTING AS THE SOLUTION TO MANAGING THE VOLUME OF DATA GENERATED IN THE COURSE OF SUCH STUDIES, AND SUGGESTS THAT THE DEVELOPMENT OF "SOPHISTICATED DATA-PROCESSING EQUIPMENT AND COMPUTER SOFTWARE PROGRAMS IS ONE AREA IN WHICH JAPAN COULD ASSUME SUBSTANTIAL RESPONSIBILITY. "

3. THE EDITORIAL STATES THAT JAPAN "ALREADY HAS GAINED CONSIDERABLE EXPERIENCE" IN REMOTE SENSING THROUGH THE OPERATION OF ITS MARINE OBSERVATION SATELLITE (MOS-1), AND THAT ITS FUTURE EARTH RESOURCES SATELLITE (ERS-1) WILL BE EQUIPPED WITH "INTRICATE INSTRUMENTATION, "INCLUDING A SYNTHETIC APERTURE RADAR. THESE TWO SATELLITE SYSTEMS, "POSSIBLY WITH SOME OTHERS," ARE DESCRIBED AS CONSTITUTING A "MAJOR PART" OF THE OVERALL PROGRAM OF GLOBAL CHANGE RESEARCH. THE EDITORIAL ALSO PROPOSES JAPANESE PARTICIPATION IN MISSION TO PLANET EARTH THROUGH THE LAUNCH "OF SOME OF THE REQUIRED SATELLITES."

4. COMMENT: THE EDITORIAL'S SPECIALIZED FOCUS, PROGRAMMATIC/TECHNICAL DETAIL AND TIMING ARE EXTRAORDINARY, AND POSSIBLY INDICATE A JAPANESE INTENT TO ASSUME A GREATER ROLE IN GLOBAL CHANGE STUDIES AND THEIR RELATED SPACE APPLICATIONS. NOAA SCIOFF SPECULATES THAT THIS COMMENTARY MAY HAVE BEEN GHOSTWRITTEN AND PURPOSELY RUN PRIOR TO THE VISIT OF THE VICE-PRESIDENT-- A VISIT WHICH ADDRESSED BILATERAL COOPERATION IN SPACE SCIENCE AND APPLICATIONS. EDITORIAL SUGGESTIONS FOR JAPANESE PARTICIPATION IN "INTERNATIONAL GLOBAL CHANCE STUDIES THROUGH

COMPUTING/DATA MANAGEMENT, REMOTE SENSING AND LAUNCH SERVICES ALSO COINCIDE NICELY WITH:

A) JAPANESE INTERESTS IN SATELLITE MONITORING OF THE ENVIRONMENT,

B) ENVIRONMENTAL INITIATIVES AT THE RECENT ECONOMIC SUMMIT AND ELSEWHERE,

C) ONGOING EFFORTS TO DEVELOP NATIONAL REMOTE SENSING SYSTEMS AND LAUNCH VEHICLES, AND

D) REITERATED STATEMENTS OF DESIRE FOR INTERNATIONAL COOPERATION IN SPACE ACTIVITIES.

16 C007A

Information on the 1991 - launch satellite, the Earth Resources Satellite (ERS-1), was posted. The stated purpose of this satellite is to observe SAR observation technology through monitoring of the natural environment. Plans are to lift this 2-year lifetime satellite into orbit with an H-I rocket. Sensor resolution specs for this bird are as follows:

SAR Resolution 18km
Optical Sensor 18.3 x 24.2 m

25 C016A

A R&D MODEL OF SAR ANTENNA

SEE PAGE# C001A FOR DETAILS

21 C012A

Japan's first Earth observation satellite, MOS-1, is about to be launched, and the follow-on, ERS-1, is now under development. Moreover, the future earth observation program, including participation in the Polar Platform Program which is now under study within NOAA, NASA, ESA, is also studied in Japan.

The main mission objectives are as follows:

1) to establish the technologies of Earth observation from space by the Synthetic Aperture Radar and Optical Sensors.

2) to explore non-renewable resources and to monitor land use, agriculture, forestry, fishery, environmental protection, prevention of natural disasters, surveillance and coastal regions, ect.

BASIC SAR SPECIFICATIONS

WAVELENGTH	L-BAND
POLARIZATION	H-H
BAND NUMBER	-
SPATIAL RESOLUTION	18m
OFF NADIR ANGLE	35
SWATH WIDTH	75Km
STEREOSCOPIC IMAGING	-

12 C003B

Japanese Earth Resources Satellite-1 (JERS-1) is scheduled for launched in February 1992 and will be launched by H-I rocket from Tanegashima Space Center, NASDA. Space segment of the JERS-1 is jointly developed by NASDA and JAROS and ground segment is developed by Earth Observation Center (EOC), NASDA. The JERS-1 has two observation equipments: synthetic aperture radar (SAR)

and optical sensor (OPS). Main mission objectives of JERS-1 are to evaluate newly developed sensors and spacecraft and to collect data of the earth concerning resources exploration, geology, agriculture, forestry, land use, prevention of disaster, coastal monitoring, sea ice monitoring and others.

Table 1. Specifications of JERS-1 SAR

Altitude	568 km
Transmit Frequency	L band (1.275 GHz)
Polarization	H-H
Swath Width	75 km
Off-nadir Angle	35 degree
Incident Angle	38.7 degree (Center of Swath Width)
Transmitted Pulse	
Type	linear down chirp
Bandwidth	15 MHz
Initial Frequency	1282.5 MHz
Pulse Length	35 sec
Sampling Rate	17.1 MHz
Pulse Repetition Frequency (PRF)	1505-1605 in 25H2 increments (1505.8, 1530.1, 1555.2, 1581.1, 1606.0)
Noise Equivalent	-20.5 dB
Signal to Ambiguity (S/A)	>14 dB
Raw Data Bit Precision	3I/3Q
Raw Data Rate	30x2 Mbps

14 C005A

SEE PAGE# C001A FOR DETAILS

18 C009A

ABSTRACT

A synthetic Aperture Radar (SAR) is one of the most promising microwave sensors for earth observation. National Space Development Agency of Japan (NASDA) has successfully completed the research and development (R&D) on the synthetic aperture radar for earth observation satellites, such as the Japan's earth observation satellite-1 (J-ERS-1), which is to be launched in FY 1990.

NEC Corporation has researched and developed the SAR transmitter and receiver under the direction of NASDA. The fundamental policy in the research and development of the SAR was to get better image quality than that of the SEASAT SAR.

2. DESIGN DESCRIPTION

To obtain high quality SAR imagery, a highly stable oscillator is necessary. The short term frequency stability of 4 x 10-10 rms/sec is determined on the basis of coherent radar condition and the acceptable phase error of the oscillator is assumed to be less than 0.1 rad. during 5 msec.

The transmission power is determined from the specified S/N ratio of 7dB. This leads the required transmission peak power to be 1050W at the duplexer output. In order to realize such a high peak value, two 800W amplifier are used. However, the designed transmission power in the R&D model is lowered to 780W because a previously fabricated

600W ampl:fier is combined with a 800W amplifier.

The bandwidth was determined to meet the spatial resolution of 25m at the off-nadir angle or 33 degrees.

4. CONCLUSION

Thermal vacuum and vibration tests were executed on some critical components, i.e., the oscillator, the high power amplifier, the power supply for the high power amplifier and the chirp pulse generator. The tests results proved that the thermal and structural design was satisfactory. We have also verified subsystem designs by evaluating the SAR R&D model.

SAR SYSTEM

FREQUENCY	L-Band
Polarization	H-H Linear
ORBIT HEIGHT	570 KM
SWATH WIDTH	75 KM
OFF-NADIR ANGLE	33 DEG
RESOLUTION	25m x 25m
SIGNAL-TO-NOISE RATIO	7 DB
MULTI-LOOK NUMBER	4
SIGNAL TO AMBIGUITY RATIO	20 DB

19 C010A

2. Japanese Earth Resources Satellite-1 (JERS-1)

JERS-1 is a remote sensing satellite designed to gather image data which are useful to explore earth resources. It will be launched in 1992 in Japan. Its weight is 1.4 tons and the altitude of its orbit will be 568 km.

JERS-1 has two kinds of imaging systems. One is synthetic aperture radar (SAR) and the other is optical sensor. The wavelength of SAR is L band and the resolution of SAR image is 18 m. The swath width of both sensors is 75 km. The ground resolution of optical sensor is 18.3m x 24.0 m for the nadir looking sensor and about 19.1m x 24.0m for the forward looking sensor. The nadir looking sensor takes seven band images in the wavelengths of visible, near infrared and shortwave infrared. The forward looking sensor takes one band image in shortwave infrared wavelength.

The combination of a nadir looking sensor image and a forward looking sensor image produces stereoscopic vision. The base-to-height ratio of JERS-1 stereoscopic images is fixed to 0.3. This ratio cannot be enlarged because the nadir looking sensor and the forward looking sensor must be placed in the same telescope due to considerations of weight limitations, etc.

24 C015A

SOME TEST RESULTS OF SAR TRANSMITTER & RECEIVER

A synthetic aperture radar (SAR) is one of the promising microwave active sensors for earth observation. National Space Development Agency Of Japan (NASDA) is researching and developing the synthetic aperture radar for the earth observation satellite in the near future such as the ERS-1 of Japan. The summary of the results are shown below.

* 600 watts of output power was obtained from one solid state amplifier.

* 4 x 10^-10 rms/sec frequency stability in short time period was obtained by oven controlled crystal oscillator.

* The electrical design technique of the high TBP chirp modulator using SAW DDL has been established.

9 C001A

The SAR, considered the most promising microwave sensing technique, is an active sensor which transmits pulses diagonally to the Earth's surface and detects renected waves. It uses the L band (24 centimeter wavelength) which is not affected by clouds or rain, making observation possible regardless of weather or light conditions. Use of pulse compression and synthetic aperture techniques results in resolution at least equal to that of optical systems. "

SAR Specifications

Frequency	1275 MHz
Polorizotion	H-H
Off-nadir angle	35 deg
Resolution	
Range	18 m
Azimuth	18 m (in 3 looks)
Swath width	75 km
Noise equivalent o deg.	-20.5 dB (max.)
S/A	14 dB (min.)
Quantization	3 bits
Output date rate	30 Mbps x 2 ch

PAGE# C002A

A delayed-action reflector is proposed for external radar calibration. Accurate calibration is expected by the reduction of the back-scattering from the background terrain and a smaller reflector can be used, so that the radar state is not influenced during the imaging of the terrain with calibration

PAGE# C005A

Verification of the range and azimuth focusing capabilities is most important but very difficult in the development of a spaceborne synthetic aperture radar (SAR). Amplitude and phase errors in the transmitted chirp pulse and the relating transmission circuits contribute to the focusing capability. This paper describes the pulse compression test principle and the test results on the bread-board model of the spaceborne SAR for the Japanese Earth Resources Satellite 1 (J-ERS-1), and also describes the

usefulness of pulse compression test method for evaluation of the SAR transmitter-receiver in the view of range focusing capability.

Summary and Conclusions

The pulse compression test is useful and promising tool for SAR system performance verification.

Pulse compression ratio of more than 392 specified in Table 1 has been obtained.

The phase and amplitude errors of the SAR transmitter and receiver have been quantitatively measured.

The phase and amplitude error allocation to the SAR transmitter receiver have been verified.

Table 1 Transmitter-receiver Characteristics

parameter	specifications
Frequency	1275 MHz
Signal bandwidth	> 12 MHz
Pulsewidth	35 +- 0.5 us
Pulse compression ratio	>392
PRF	1520-1670pps
Frequency stability	4 X 10^-10 rms/s +- 5 X 10-6/2 years
Transmitter Peak Power	1050 W min
Receiver noise figure	4.6 dB max
AGC/MGC	70 - 92 dB, 1 dB step
STC	0 - 5 dB, 1 dB step
Receiver bandwidth	13 MH

PAGE# C016A

A R&D MODEL OF SAR ANTENNA

This paper presents the test results of a R&D model of SAR Antenna (SARA) for the Japanese ERS-1 satellite. During testing of our R&D models, critical structural & mechanical components test, electrical performance test, deployment test and thermal deformation test were performed and an environmental test model is being developed. Of these tests, the presentation is concerned with deployment test, thermal deformation test and 128 element test. From the results of these tests, we did not find any notable discrepancies and test data which satisfied the requirements was obtained

22 C013A

EARTH RESOURCES SATELLITE-1 (ERS-1)

* ESTABLISHMENT OF REMOTE SENSING TECHNOLOGY BY USING SYNTHETIC APERTURE RADAR AND OPTICAL SENSORS THROUGH MONITORING THE NATURAL ENVIRONMENT INCLUDING NATURAL RESOURCES, AGRICULTURE, FORESTRY AND FISHERIES.

* MISSION EQUIPMENT: SAR (SYNTHETIC APERTURE RADAR)
OPS (OPTICAL SENSORS- VISIBLE & NEAR INFRARED RADIOMETER)

* MISSION LIFE: 2 YEARS
* ORBIT: SUN-SYNCHRONOUS (ALTI:570 km, INC: 98 DEG)
* LAUNCH DATE/VEHICLE: 1992 H-I-7
* OPERATOR OF SATELLITE: NASDA
* USERS: MULTI USERS
* PRIME CONTRACTOR: MELCO FOR SPACECRAFT BUS

2 C0000

PHASED ARRAY ANTENNA, CORPORATE FEED, ACTIVE

Phased Array Antenna

The phased array antenna may be designed either as a planar (flat surface) or conformal (curved surface) array, and it will contain a large number of small antenna elements which are uniformly spaced in both the x and y directions along the radiating surface of the antenna array. An array may be designed as a transmit antenna, a receive antenna, or a common aperture antenna which combines both transmit and receive functions. In the latter type of array each of these antenna elements serves both transmit and receive functions and may be colocated with their corresponding "phase shifter". The radar beam that is projected from the surface of this antenna array may be rapidly steered or scanned in space, without movement of the antenna structure, by controlling and varying the phase relationships between adjacent phase shifters. This electronic steering can be much faster and much more reliable than other systems that require continual motion of the antenna to scan a target area with the radar beam.

Active Array Design

While virtually all phased array antennas will usually have their antenna element/phase shifter assemblies uniformly distributed in a matrix pattern across the front surface, one of "Active" design will also have a substantial portion of both the transmit and receive functions dispersed across the antenna array, in the form of miniature (solid state) TR modules. Every system will have a central transmitter assembly that produces the waveform of the transmitted pulse and establishes the timing, and they will also have a central receiver assembly that collects the radar return signal from the antenna elements, but in active (or distributed) systems the functions of logic, amplification and phase shifting, for both the transmit and receive functions, are distributed to a large number of TR modules installed in the antenna array. In the most extreme case a separate TR module is colocated with every antenna element, and beyond that there are many lesser levels of distribution ranging from one TR module for two elements down to one TR module for an entire branch of antenna elements in the corporate feed network. At any level of distribution the resulting system is much more reliable because it is now represented by a large quantity of redundant transmit and receive amplifiers and logic circuits (at the extreme, one to each antenna element) and the failure of one or more of these modules will not seriously degrade the radar performance, so long as the major portion of them continue to operate.

A typical TR module requires 6 to 15 microwave and digital circuits to perform the necessary functions. Reasonable radar systems require from 1000 to 15,000 modules per array to achieve the desired performance or from 10,000 to 200,000 microwave and

digital circuits in the microwave portion of a solid-state phased array. For this to be an economical approach, the cost per circuit must be in the range of $1 to 5$ each.

Corporate Feed

The radar pulses created by the transmitter assembly are distributed to each of the antenna element/phase shifter assemblies (dispersed across the surface of the array) through a network of microwave plumbing that has been layed out in a pattern that resembles a corporate organization structure. This network of waveguide serves to distribute the transmitter pulses to each radiating element and, to conduct the radar return signal from the array of antenna elements back to the central receiver. Active arrays with corporate feeds will have (depending upon the design) anywhere from a few to a very large quantity of transmit and receive amplifiers or complete TR modules located within the branches of the feed network.

20 C011A

ARRAY ANTENNA FOR SYNTHETIC APERTURE RADAR

FREQUENCY	1275 +- 6MHz
GAIN	>= 33.7dbi
BEAM WIDTH	1.0 x 6.2
SIDELOBE LEVEL	-13dB (E PLANE) -18dB (H PLANE)
POLARIZATION	HORIZONTAL
VSWR	<= 1.5
DIMENSION	11.92x2.06x0.02 m
WIEGHT	<= 135 kg

3 C0000

PHASED ARRAY ANTENNA, CORPORATE FEED, PASSIVE

Phased Array Antenna

The phased array antenna may be designed either as a planar (flat surface) or conformal (curved surface) array, and it will contain a large number of small antenna elements which are uniformly spaced in both the x and y directions along the radiating surface of the antenna array. An array may be designed as a transmit antenna, a receive antenna, or a common aperture antenna which combines both transmit and receive functions. In the latter type of array each of these antenna elements serves both transmit and receive functions and may be collocated with their corresponding "phase shifter". The radar beam that is projected from the surface of this antenna array may be rapidly steered or scanned in space, without movement of the antenna structure, by controlling and varying the phase relationships between adjacent phase shifters. This electronic steering can be much faster and much more reliable than other systems that require continual motion of the antenna to scan a target area with the radar beam.

Passive Array Design

While virtually all phased array antenna will usually have the antenna element/phase shifter assemblies uniformly distributed in a matrix pattern across the front surface, one of "Passive" design may or may not have the radar receiver function also dispersed across the surface of the antenna, in the form of miniature (solid state) receiver modules, collocated with the antenna element/phase shifter assemblies. In such systems where (there is a central transmitter, but) most of the receiver is distributed throughout the antenna, the receive function of the system is much more reliable because it is now represented by a

large quantity of redundant receivers (at the extreme, one at each antenna element) and the failure of one or more of these modules will not seriously degrade the radar performance, so long as the major portion of them continue to operate.

Corporate Feed

The radar pulses created by the transmitter assembly are distributed to each of the antenna element/phase shifter assemblies (dispersed across the surface of the array) through a network of microwave plumbing that has been layed out in a pattern that resembles a corporate organization structure. This network of waveguide serves to distribute the transmitter pulses to each radiating element and, in systems with a central (non-distributed or partially distributed) receiver, it also serves to conduct the radar return signal from the array of antenna elements back to the central receiver. Passive array designs with corporate feeds will have few (or none) transmit or receive amplifiers located within the branches of the feed network.

26 C016B

A R&D MODEL OF SAR ANTENNA

SEE PAGE# C001A FOR DETAILS

5 C0000

PHASED ARRAY ANTENNA, LENS FEED, ACTIVE

Phased Array Antenna

The phased array antenna may be designed either as a planar (flat surface) or conformal (curved surface) array, and it will contain a large number of small antenna elements which are uniformly spaced in both the x and y directions along the radiating surface of the antenna array. An array may be designed as a transmit antenna, a receive antenna, or a common aperture antenna which combines both transmit and receive functions. In the latter type of array each of these antenna elements serves both transmit and receive functions and may be colocated with their corresponding "phase shifter". The radar beam that is projected from the surface of this antenna array may be rapidly steered or scanned in space, without movement of the antenna structure, by controlling and varying the phase relationships between adjacent phase shifters. This electronic steering can be much faster and much more reliable than other systems that require continual motion of the antenna to scan a target area with the radar beam.

Active Array Design

While virtually all phased array antennas will usually have their antenna element/phase shifter assemblies uniformly distributed in a matrix pattern across the front surface, one of "Active" design will also have a substantial portion of both the transmit and receive functions dispersed across the antenna array, in the form of miniature (solid state) TR modules.

Every system will have a central transmitter assembly that produces the waveform of the transmitted pulse and establishes the timing, and they will also have a central receiver assembly that collects the radar return signal from the antenna elements, but in active (or distributed) systems the functions of logic, amplification and phase shifting, for both the transmit and receive functions, are distributed to a large number of TR modules installed in the antenna array. In the most extreme case a separate TR module is colocated with every antenna element, and

beyond that there are many lesser levels of distribution ranging from one TR module for two elements down to one TR module for an entire branch of antenna elements in the corporate feed network. At any level of distribution the resulting system is much more reliable because it is now represented by a large quantity of redundant transmit and receive amplifiers and logic circuits (at the extreme, one to each antenna element) and the failure of one or more of these modules will not seriously degrade the radar performance, so long as the major portion of them continue to operate.

A typical TR module requires 6 to 15 microwave and digital circuits to perform the necessary functions. Reasonable radar systems require from 1000 to 15,000 modules per array to achieve the desired performance or from 10,000 to 200,000 microwave and digital circuits in the microwave portion of a solid-state phased array. For this to be an economical approach, the cost per circuit must be in the range of $1 to 5$ each.

Lens Feed

In a lens fed (or optically fed) array the antenna elements have features on both surfaces of the array. The elements on the surface facing the target perform in the same manner as those in a corporate fed array, they project the transmitted radar wave and receive the radar return signal from the target. Those radiators of the elements located on the opposite surface of the array provide coupling to the transmitter and receiver horns. The radar pulses created by the transmitter assembly are distributed to each of the antenna element/phase shifter assemblies (dispersed across the surface of the array) as a beam projected from the transmit horn (or array of transmit horns) facing the coupling surface of the array. These elements pass the signal through the phase shifters which, working under computer control, focus and steer the beam, projecting it into space from the elements on the opposite face of the array.

Other antennas are hybrid designs that combine these approaches and some even use curved or flat reflector planes in combination with a phased array.

6 C0000

PHASED ARRAY ANTENNA, LENS FEED, PASSIVE

Phased Array Antenna

The phased array antenna may be designed either as a planar (flat surface) or conformal (curved surface) array, and it will contain a large number of small antenna elements which are uniformly spaced in both the x and y directions along the radiating surface of the antenna array. An array may be designed as a transmit antenna, a receive antenna, or a common aperture antenna which combines both transmit and receive functions. In the latter type of array each of these antenna elements serves both transmit and receive functions and may be colocated with their corresponding "phase shifter". The radar beam that is projected from the surface of this antenna array may be rapidly steered or scanned in space, without movement of the antenna structure, by controlling and varying the phase relationships between adjacent phase shifters. This electronic steering can be much faster and much more reliable than other systems that require continual motion of the antenna to scan a target area with the radar beam.

Passive Array Design

While virtually all phased array antennas will usually have their

antenna element/phase shifter assemblies uniformly distributed in a matrix pattern across the array surface, one of "Passive" design may or may not have a portion of the receive function dispersed across the antenna array, in the form of miniature (solid state) TR modules.

Every system will have a central transmitter assembly that produces the waveform of the transmitted pulse and establishes the timing, and they will also have a central receiver assembly that collects the radar return signal from the antenna elements, but a passive system may have the logical control, amplification and phase shifting, for the receive function, distributed to a large number of modules installed in the antenna array. In the most extreme case a separate module is colocated with every antenna element, and beyond that there are many lesser levels of distribution ranging from one module for two elements down to one module for an entire group of antenna elements. In a lens fed system, an array may be divided into a number of sub arrays, each driven by its own transmit/receive horn, or by one horn in an array of horns.

In those systems where a portion of the receiver is dispersed across the antenna array, the system is more reliable because the distributed functions are now performed by a large quantity of (redundant) modules and the failure of one or more of these modules will not adversely affect the system performance as long as the remainder continue to operate.

Lens Feed

In a lens fed (or optically fed) array the antenna elements have features on both surfaces of the array. The elements on the surface facing the target perform in the same manner as those in a corporate fed array, they project the transmitted radar wave and receive the radar return signal from the target. Those radiators of the elements located on the opposite surface of the array provide coupling to the transmitter and receiver horns. The radar pulses created by the transmitter assembly are distributed to each of the antenna element/phase shifter assemblies (dispersed across the surface of the array) as a beam projected from the transmit horn (or array of transmit horns) facing the coupling surface of the array. These elements pass the signal through the phase shifters which, working under computer control, focus and steer the beam, projecting it into space from the elements on the opposite face of the array.

Other antennas are hybrid designs that combine these approaches and some even use curved or flat reflector planes in combination with a phased array.

7 C0000

REFLECTOR ANTENNA, ELECTRONIC SCAN

The parabola is the most common shape of the reflector employed in this antenna design. When properly illuminated by a point source (or proper feed) at the focus of the parabola the antenna projects a nearly symmetrical pencil- beam antenna pattern. In space-based systems the reflecting surface is usually constructed of an expanded metal mesh or metal net that is light weight and easily deployable using an umbrella-like structure or a hoop and column structure. The axis of this type of antenna is aimed at the target area either by rotating the antenna gimbal structure or by positioning of the satellite.

Scanning of the beam over the target area, by scanning the reflector through mechanical means, would however upset the

dynamics and stability of the spacecraft, and thus it is most often accomplished by instead scanning the feed either mechanically or electronically, (in one design) by use of an electronically scanned sub-reflector. Regardless of the scanning technique a parabola cannot be scanned more than +/- 10 beamwidths off axis with serious deterioration of the antenna beam quality. Other designs that minimize these losses use different reflector contours.

4 C0000

REAL-TIME SIGNAL PROCESSOR

Optical Signal Processors

Earlier SARs employed optical (analog) signal processors, which are intrinsically fast and can produce high resolution images, but because they involve a photographic film step and both heavy and bulky equipment, the radar data had to be returned to the ground for processing. This system uses an intensity-modulated scanner that photographically records he coherent video output of the radar receiver in a two-dimensional raster format on film. This recording is essentially a halogram of the radar map. After the film has been developed, coherent light from a laser is projected through it and a sophisticated system of lenses focuses the light onto a second film in a manner that combines the range and doppler information contained in the recorded video data into an image.

While the size and weight of these earlier systems and the delay inherent in the development processing of the photographic film precluded real-time on-board processing, current research promises to eliminate the need for photographic recording and thus make onboard operation in spacecraft possible.

Digital Signal Processors

With the advent of low-cost high-speed integrated solid-state circuits, it has become possible to process the video signals digitally in real time with equipment that is small and light Enough to be incorporated in aircraft and probably in spacecraft. Digital processing has the advantage of being extremely accurate, fast and versatile, making it possible to vary the range the scale, the resolution and the format of the processed image, on demand.

17 C008A

ABSTRACT

National Space Development Agency of Japan (NASDA) conducted SAR-580 experiment from October through November , 1983 by using synthetic aperture radar (SAR) with variable parameters mounted on the aircraft Convair 580 owned by Canada Centre for Remote Sensing (CCRS) . The objectives of this experiment are to evaluate parameters of SAR mounted on Japanese Earth Resources Satellite 1 (ERS-1), to develop SAR data processing method, to evaluate utilization of SAR data in various application fields and to study future advanced SAR. In order to achieve these objectives, NASDA developed SAR data digital processing scftware and processed about 100 scenes of SAR-580 data. By using "auto focusing method" , outstanding quality of SAR imagery was obtained. In this paper the outline of the SAR data digital processing method and some images are presented.

DIGITAL PROCESSING METHOD

In order to obtain high resolution SAR imagery, it is necessary to estimate SAR parameter more precisely. Consequently, NASDA employed for the first time "auto-focusing method" both in the azimuth and range direction.
The characteristics of the software developed by NASDA are as follows:

(1) By using "auto-focusing method" both in the azimuth and range direction, smear in the output image is the smallest as much as possible.

(2) Selective multi-look function by using spatial filters is employed to produce the desired number of look images from a single look image.

(3) Resolution simulation function is employed to simulate space-borne SAR data.

(4) It is possible to cancel and restart processing at any steps.

(5) It is easy to define the size of processed image and change processing parameter.

(6) It is possible to input raw SAR data of either CCRS format or ERIM format for CCT.

(7) Output SAR image CCT is CCRS format based upon world standard super structure used for Landsat MSS/TM.

NASDA processed some SAR-580 raw CCT data by using FACOM M-200 located at Tsukuba Space Center, NASDA. It takes about two hours to process SAR raw data and produce SAR imagery (azimuth 10 km x range 8 km, pixel size 1.5 m) in February, 1984 when the first raw CCT data was available. The image quality is more excellent than expected. About 30 pass SAR raw data in 8 test sites (Tsukuba, Hiratsuka, Off-shore of Hiratsuka, Oshima, Miyakezima, Fuji, Akita (Futatsui) , Shizukuishi-Kosaka) were obtained and it was necessary to process many scenes for computer NEC NEDIPS located at RESTEC, about 100 scenes were processed in 1984 FY.

Conclusion

SAR-580 experiment was successfully conducted in collaboration of CCRS and related agencies. One of great results is to develop SAR-580 data processing software which will be promising for spaceborne SAR such as Japanese ERS-1 SAR. Based upon these results, software for ERS-1 SAR will be developed in near future.

11 C003A

Data Processing and Calibration of SAR Data in Japan

Japanese Earth Resources Satellite-1 (JERS-1) will be launched from Tanegashima Space Center, NASDA by H-I rocket in February 1992. The JERS-1 has two observation equipments: synthetic aperture radar (SAR) and optical sensor (OPS) which consists of visible, near-infrared and short-wave infrared radiometer. In order to evaluate parameters of SAR, to develop processing and

calibration method and to evaluate the utility of SAR data in various fields of applications, NASDA conducted SAR-580 experiment by using variable parameter SAR mounted on Convair 580 owned by Canada Centre for Remote Sensing (CCRS) during October and November, 1983 in collaboration with many research organizations. As a part of this experiment, NASDA conducted calibration experiment in Tsukuba where several corner reflectors were set up. NASDA processed about 100 scenes of SAR-580 by newly developed autofocusing method and evaluated SAR data from various points of view. Moreover, Communications Research Laboratory (CRL) participated in SIR-8 experiment planned and conducted by JPL in collaboration with several agencies including NASDA. Ground segments of the JERS-1 are developed by EOC, NASDA. Ground system for JERS-1 is under conceptual design in 1988.Basic design will begin in 1989. In order to develop processing system, it is necessary to define processing data volume, data type and processing level for JERS-1 data. In this case, both SAR data and OPS data should be considered. Since the velocity of SAR is about 7km/sec and PRF is 1505.8-1606.0, sampling interval is about 4.5m. So, pixel size of 1 and 3 looks are defined as 3.125m and 12.5m, respectively. Spatial resolution of SAR is 18m (3 looks) and 6m (1 look). Though there are many window functions, typical window functions (Square, Riesz, and Hamming) can be selected. Concerning output data type, both amplitude and logarithmic expression can be selected by considering dynamic range. Since the logarithmic expression provides quasi-normal distribution, this is desirable in case of land use classification by combining with optical sensor data and using maximum likelihood method.

Table 1. Specifications of JERS-1 SAR

Raw Data Bit Precision	3I/3Q
Raw Data Rate	30x2 Mbps

Table 2. Tentative processing level of JERS-1 SAR data

Level 0:	Raw data
Level 1:	Basic image (Range and Azimuth Compression)
Level 2:	System corrected (Bulk) image Radiometrically and geometrically corrected image)
Level 3:	Precisely corrected image by using GCP.
Level 4:	Precisely corrected image by using Digital Terrain Model (DTM)

Table 3. Tentative JERS-1 SAR data processing types

Map Projection Method:	UTM (Universal Transverse Mercator), SOM (Space Oblique Mercator), PS (Polar Stereo)
Resampling Method	Nearest Neighbor Cubic Convolution
Frame Size	75km x 75km
Pixel Size	3.125m (1 look) 12.5m (3 looks)
Window Function	Square, Riesz, Hamming
Output Data Type	Amplitute/Logarithmic expression
Recording Format (CCT)	Super structure (Based upon CEOS WGD SAR format standardization)
Recording density(CCT)	6250 BPI, 1600 BPI
Number of Tracks (CCT)	9

The SAR's linearity frequency-modulated microwaves, called chirp signals, are transmitted to the Earth's surface and reflected, creating a hologram. An image processor called NEDIPS will rapidly convert the holographic data from ERS- 1 's SAR into a clear, very-high-resolution image.

The NEDIPS non-Von Neumann general-purpose high-speed computer was developed in 1983 for processing synthetic aperture radar data. Since then, the NEDIPS hardware and software have been improved and expanded. At present, NEDIPS is used for parallel processing in scientific applications as well as for SAR processing. A system in which multiple processing units are connected in a ring configuration, NEDIPS is connected by two lines to a host computer which controls it and transfers data at a speed of up to 106 megabytes per second.

NEDIPS versions include Model 10 (one processing unit), Model 20 (two processing units), and Model 30 (three processing units). A low-order model can be upgraded by adding one or more processing units and other optional modules.

In processing SAR data, NEDIPS performs a 4,096-point complex fast Fourier transform (FE=r). More than 800,000 operations are required to process one scene of about 100 x 100 kilometers. The cpu time is about 100 hours on a large general purpose computer such as the ACOS System 700, but the NEDIPS/host-computer combination produces a clear image in about 3. 5 hours.

NEDIPS performs spatial filtering and FFT filtering to eliminate the noise contained in the image and enhance contrast. It can process a 256 x 256-pixel image in about 0.1 second. NEDIPS also performs two-dimensional FtT filtering (which repeats one-dimensional FFT filtering in both the longitudinal and transverse directions) and can process a 256- x 256-pixel image in about one second.

ADEOS Advanced Earth Observation Satellite

ADEOS is Japan's next-generation earth observation satellite. Currently in the conceptual and preliminary design phase, the satellite is scheduled for launch in 1993. ADEOS, weighing 2.8 tons including a mission payload of 800 kilograms, will carry two advanced optical sensors: an ocean color and temperature scanner (OCTS) and an advanced visible and near-infrared radiometer (AVNIR). In January 1988 Japan called for participation by the international community in the ADEOS program.

15 C006A

ABSTRACT

The important point in designing a image processing system is to minimize the error of the summing of the products. The 16 bit VLSI including a 32 bit multiplier was designed based on this reason. The design concept of this system and the experimental results of the breadboard model were presented at IGARSS'85. This custom VLSI was developed, and presented at ISSCC'86. An image processing system has been developed. It consists of the data memories, interface circuits, the VLSI's, and the vision processing

system which was presented at the 2nd ISRR '84. The complex FFT on 1,024 points was done in two miliseconds with one VLSI. Tests have revealed that this system is suitable for the image reconstruction of SAR as well as for the processing of the images taken optical sensors.

Results

Software was prepared and an image data processing experiment was conducted with the system. An important and time-consuming process was selected for the experiment. The complex FFT processing on 1,024 points was done in two milli-seconds with one VLSI. Image processing of 512X512 pixels either of Affine transform or of histogram was done in 0.1 second and that of a spatial filter with a 3X3 mask was done in 0.3 seconds. i.e. : The time for processing by one T9506 VLSI is same as Table 1. This corresponds to the SAR image reconstruction time of one hour for a 100 km x 100 km.

Conclusion

The outlook for a precise and fast processing system is good, e.g. a 100 km x 100 km SAR image formation will be done within six minutes or a 185 km x 185 km TM image radiometric correction will be done in 38 sec. with 16 VLSIs in parallel operation.

Table 1

Function (32 Bit Precision)	Processing Time
1024 points complex FFT	2.0 ms
Affine Transform	400 ns/pixel
3x3 Spatial Filter	1.0 us/pixel
Histogram	400 ns/pixel

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX D

ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT (ACSHS)

1206010A01 - ACSHS - SYSTEM PERFORMANCE

1002030A01 - GYROSCOPE - FLOATED

1002040A01 - GYROSCOPE - DRY TUNED

1002050A01 - GYROSCOPE - RING LASER (RLG)

1002070A01 - GYROSCOPE - FIBER OPTIC (FOG)

1206040A01 - THRUSTER - GAS

1206050B01 - STAR SENSOR - CHARGE COUPLED DEVICE

1206050B02 - STAR SENSOR - IMAGE DISSECTOR

1206050B03 - EARTH SENSOR

1206050B04 - SUN SENSOR - ANALOG

1206050B05 - SUN SENSOR - DIGITAL

1206060A01 - CONTROL MOMENT GYRO - SINGLE GIMBAL

1206060A02 - CONTROL MOMENT GYRO - DOUBLE GIMBAL

1206060A03 - REACTION WHEEL

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** *** SUB-TECHNOLOGY: GYROSCOPE - FLOATED

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
10020 30A01	A	BL		B	D0000		Y	

** *** SUB-TECHNOLOGY: GYROSCOPE - DRY TUNED

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
10020 40A01	A	BL		B	D0000		Y	
10020 40A01	A	JA	C	P	D003A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
10020 40A01	A	JA	E	S	D012A	D019A	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
10020 40A01	A	JA	C	P	D019A	P	Y	NATIONAL SPACE AGENCY OF JAPAN (NASDA)
10020 40A01	A	JA	E	P	D046A	P	Y	NIPPON PRECISION CO. LTD.

** *** SUB-TECHNOLOGY: GYROSCOPE - RING LASER (RLG)

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10020 50A01	A	BL		B	D0000		Y	
10020 50A01	A	JA	E	S	D004A	D038A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
10020 50A01	A	JA	E	S	D006A	D038A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
10020 50A01	A	JA	E	S	D011A	D038A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
10020 50A01	A	JA	E	P	D038A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
10020 50A01	A	JA	E	P	D040A	P	Y	JAPAN AVIATION ELECTRONICS
10020 50A01	A	JA	E	S	D044B	D040A	N	JAPAN AVIATION ELECTRONICS

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** *** SUB-TECHNOLOGY: GYROSCOPE - FIBER OPTIC (FOG)								
10020 70A01	A	BL		B	D0000		Y	
10020 70A01	A	JA	E	P	D009A	P	Y	OPTOELECTRON. TECHNOL. RES. CORP. c/o SHARP CORP. CENTRAL RES. LABS.
10020 70A01	A	JA	E	P	D036A	P	N	OPTOELECTRONIC INDUSTRY & TECHNOLOGY DEVELOPMENT ASSOCIATION (OITDA)
10020 70A01	A	JA	E	P	D037A	P	Y	HITACHI LTD.
10020 70A01	A	JA	E	S	D040B	D044B	Y	JAPAN AVIATION ELECTRONICS
10020 70A01	A	JA	E	P	D042A	P	Y	UNIVERSITY OF TOKYO, RESEARCH CENTER FOR ADVANCED SCIENCE AND TECHNOLOGY
10020 70A01	A	JA	E	P	D043A	P	Y	MITSUBISHI ELECTRIC CORPORATION, CENTRAL RESEARCH LABORATORY
10020 70A01	A	JA	C	S	D044C	D044B	Y	JAPAN AVIATION ELECTRONICS (JAE)
10020 70A01	A	JA	E	P	D047A	P	Y	MITSUBISHI PRECISION COMPANY, LTD.
10020 70A01	A	JA	B	P	D044B	P	Y	JAPAN AVIATION ELECTRONICS (JAE)
** *** SUB-TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT								
12060 10A01	A	BL		B	D0000		Y	
** *** SUB-TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT (CONT)								
12060 10A01	B	BL		B	D0000		Y	

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12060 10A01	B	JA	E	P	D005C	P	Y	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES
12060 10A01	B	JA	D	P	D008A	P	Y	UNIVERSITY OF OSAKA PREFECTURE
12060 10A01	B	JA	E	P	D013A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
12060 10A01	B	JA	E	P	D027C	P	Y	MITSUBISHI PRECISION CO., LTD.
12060 10A01	B	JA	E	P	D031A	P	Y	FUJITSU LIMITED
12060 10A01	B	JA	E	P	D035A	P	Y	MASTSUSHITA RESEARCH INSTITUTE
12060 10A01	B	JA	E	P	D039A	P	Y	NATIOANL SPACE DEVEVOPMENT AGENCY OF JAPAN
12060 10A01	B	JA	E	P	D039B	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
12060 10A01	B	JA	E	P	D039D	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
12060 10A01	B	JA	E	P	D039E	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
12060 10A01	B	JA	E	P	D044A	P	Y	JAPAN AVIATION ELECTRONICS (JAE)
12060 10A01	B	JA	E	P	D045A	P	Y	TOHOKU UNIVERSITY, ENGINEERING FACULTY
** *** SUB-TECHNOLOGY: THRUSTER - GAS								
12060 40A01	A	BL		B	D0000		Y	
12060 40A01	A	JA	B	P	D001A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 40A01	A	JA	B	P	D003D	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

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12060 40A01	A	JA	E	P	D005A	P	Y	NIPPON OIL AND FAT CO. LTD
12060 40A01	A	JA	E	P	D005B	P	Y	NIPPON SUIYAKU KOGYO
12060 40A01	A	JA	B	P	D007A	P	Y	INSTITUTE OF SPACE AND ASTRONAUTIACAL SCIENCES
12060 40A01	A	JA	C	P	D010A	P	N	MINISTRY OF POSTS AND TELECOMMUNICATIONS
12060 40A01	A	JA	E	P	D018B	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
12060 40A01	A	JA	C	P	D020C	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 40A01	A	JA	C	P	D021A	P	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 40A01	A	JA	B	P	D023A	P	Y	ISHIKAWAJIMA-HSRIMA HEAVY INDUSTRIES (IHI), SPACE DEVELOPMENT DIVISION
12060 40A01	A	JA	B	S	D023B	D023A	Y	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES (IHI), SPACE DEVELOPMENT DIVISION
12060 40A01	A	JA	E	P	D026A	P	Y	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.
12060 40A01	A	JA	C	P	D028D	P	Y	NATIONAL SPACE DEVELOPMENT AGENY OF JAPAN (NASDA)
12060 40A01	A	JA	E	S	D029A	D026A	Y	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.
12060 40A01	A	JA	D	P	D030B	P	Y	UNKNOWN
12060 40A01	A	JA	C	P	D039C	P	Y	NATIONAL SPACE DEVLOPMENT AGENCY OF JAPAN
12060 40A01	A	JA	D	P	D041A	P	Y	OSAKA UNIVERSITY

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** *** SUB-TECHNOLOGY: STAR SENSOR - CHARGE COUPLED DEVICE (CCD)								
12060 50B01	A	BL		B	D0000		Y	
12060 50B01	A	JA	C	P	D022A	P	Y	NEC CORPORATION - SPACE DEVELOPMENT DIVISION, YOKOHAMA PLANT
12060 50B01	A	JA	E	P	D030A	P	Y	UNKNOWN
12060 50B01	A	JA	B	P	D033A	P	Y	TOSHIBA CORPORATION
** *** SUB-TECHNOLOGY: STAR SENSOR - IMAGE DISSECTOR								
12060 50B02	A	BL		B	D0000		Y	
12060 50B02	A	JA	E	P	D016A	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
12060 50B02	A	JA	E	S	D016B	D016A	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
12060 50B02	A	JA	E	P	D018A	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
12060 50B02	A	JA	E	P	D027B	P	Y	TOSHIBA CORPORATION
12060 50B02	A	JA	C	P	D033B	P	Y	TOSHIBA CORPORATION
12060 50B02	A	JA	C	P	D033C	P	Y	TOSHIBA CORPORATION
12060 50B02	A	JA	D	P	D034A	P	Y	HAMAMATSU PHOTONICS K.K.
** *** SUB-TECHNOLOGY: EARTH SENSOR								
12060 50B03	A	BL		B	D0000		Y	

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12060 50B03	A	JA	B	P	D002A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 50B03	A	JA	B	P	D003C	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
12060 50B03	A	JA	E	P	D014A	P	N	MITSUBISHI ELECTRIC CORPORATION (MELCO)
12060 50B03	A	JA	E	P	D020B	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 50B03	A	JA	D	S	D021C	D021A	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 50B03	A	JA	E	P	D024A	P	Y	NATIONAL SPACE DEVELOPMET AGENCY OF JAPAN (NASDA)
12060 50B03	A	JA	E	P	D027A	P	Y	NEC CORPORATION
12060 50B03	A	JA			D028B		Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
** *** SUB-TECHNOLOGY: SUN SENSOR - ANALOG								
12060 50B04	A	BL		B	D0000		Y	
12060 50B04	A	JA	E	P	D002B	P	Y	NATIONAL SPACE DEVELPOMENT AGENCY OF JAPAN (NASDA)
12060 50B04	A	JA	E	P	D003B	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
12060 50B04	A	JA	E	P	D014B	P	N	MITSUBISHI ELECTRIC CORPORATION (MELCO)
12060 50B04	A	JA	E	P	D017A	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
12060 50B04	A	JA	E	P	D020A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASADA)
12060 50B04	A	JA	E	P	D021B	P	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)

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12060 50B04	A	JA	E	P	D028A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 50B04	A	JA	B	P	D033F	P	Y	TOSHIBA CORPORATION
12060 50B04	A	JA	D	P	D033I	P	Y	TOSHIBA CORPORATION
** *** SUB-TECHNOLOGY: SUN SENSOR - DIGITAL								
12060 50B05	A	BL		B	D0000		Y	
12060 50B05	A	JA	C	P	D033E	P	Y	TOSHIBA CORPORATION
12060 50B05	A	JA	B	P	D033H	P	Y	TOSHIBA CORPORATION
12060 50B05	A	JA	B	P	D033G	P	Y	TOSHIBA CORPORATION
** *** SUB-TECHNOLOGY: CONTROL MOMENT GYRO - SINGLE GIMBAL								
12060 60A01	A	BL		B	D0000		Y	
12060 60A01	A	JA	D	P	D016C	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
12060 60A01	A	JA	D	P	D018C	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION
** *** SUB-TECHNOLOGY: CONTROL MOMENT GYRO - DOUBLE GIMBAL								
12060 60A02	A	BL		B	D0000		Y	
12060 60A02	A	JA	D	P	D015B	P	Y	NATIONAL AEROAPCE LABORATORY
12060 60A02	A	JA	D	P	D017B	P	Y	NEC CORPORATION, SPACE DEVELOPMENT DIVISION

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12060 60A02	A	JA	E	P	D021D	P	N	NATIOANL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 60A02	A	JA	D	P	D028C	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
12060 60A02	A	JA	A	P	D030C	P	Y	UNKNOWN
12060 60A02	A	JA	C	P	D030D	P	Y	UNKNOWN
12060 60A02	A	JA	E	P	D039F	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
** *** SUB-TECHNOLOGY: REACTION WHEEL								
12060 60A03	A	BL		B	D0000		Y	
12060 60A03	A	JA	D	P	D015A	P	Y	NATIONAL AEROSPACE LABORATORY
12060 60A03	A	JA	D	P	D032A	P	Y	NAL

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: GYROSCOPE - FLOATED							
10020 30A01 A ACSHS	DRIFT RATE STABILITY --- DEG/HR/HR --- IMPR. DIR: L	SCALE FACTOR --- ARC-SECOND/PULSE --- IMPR. DIR: L	SCALE FACTOR STABILITY --- PPM/DAY --- IMPR. DIR: L	NOISE EQUIVALENT ANGLE --- DEG/HR RMS --- IMPR. DIR: L	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: GYROSCOPE - DRY TUNED							
10020 40A01 A ACSHS	DRIFT RATE STABILITY --- DEGREES/HR/HR --- IMPR. DIR: L	RANDOM DRIFT --- DEG/HR --- IMPR. DIR: L	SCALE FACTOR --- ARC-SECOND/PULSE --- IMPR. DIR: L	SCALE FACTOR STABILITY --- PPM/DAY --- IMPR. DIR: L	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: GYROSCOPE - RING LASER (RLG)							
10020 50A01 A ACSHS	G-SENSITIVE DRIFT RATE --- DEGREES/HR --- IMPR. DIR: L	DRIFT RATE STABILITY --- DEG/HR/HR --- IMPR. DIR: L	SCALE FACTOR --- ARC-SECONDS/PULSE --- IMPR. DIR: L	SCALE FACTOR STABILITY --- PPM/DAY --- IMPR. DIR: L	RATE DETECTION THRESHOLD --- ARC-SECONDS/SEC --- IMPR. DIR: L	LIFE --- YEARS --- IMPR. DIR: H	COMP
** ******************** SUB-TECHNOLOGY: GYROSCOPE - FIBER OPTIC (FOG)							
10020 70A01 A ACSHS	G-SENSITIVE DRIFT RATE --- DEGREES/HR --- IMPR. DIR: L	DRIFT RATE STABILITY --- DEG/HR/HR --- IMPR. DIR: L	SCALE FACTOR --- ARC-SECONDS/PULSE --- IMPR. DIR: L	SCALE FACTOR STABILITY --- PPM/DAY --- IMPR. DIR: L	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT							
12060 10A01 A ACSHS	POINTING ACCURACY --- ARC-SECOND --- IMPR. DIR: L	POINTING KNOWLEDGE --- ARC-SECOND --- IMPR. DIR: L	ATTITUDE MANEUVER RATE --- DEG/SECOND --- IMPR. DIR: H	ATTITUDE MANEUVER ACCELERATION --- DEG/SECOND^2 --- IMPR. DIR: H	SHAPE CONTROL - FREQUENCY RANGE --- Hz --- IMPR. DIR: H	SHAPE CONTROL - AMPLITUDE RANGE --- METER --- IMPR. DIR: L	SYS PERF

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT (CONT)							
12060 10A01 B ACSHS	VIBRATION CONTROL - FREQUENCY --- Hz --- IMPR. DIR: H	VIBRATION CONTROL - AMPLITUDE --- METERS --- IMPR. DIR: L	ORBIT ADJUST - EVASIVE MANEUVER --- G FORCE --- IMPR. DIR: H	ORBIT ADJUST - FORMATION POSITION ACCURACY (RELATIVE) --- METERS --- IMPR. DIR: L	ORBIT ADJUST - FORMATION VELOCITY ACCURACY (RELATIVE) --- METERS/SECOND --- IMPR. DIR: L	AUTONOMOUS NAVIGATION - POSITION KNOWLEDGE --- METERS --- IMPR. DIR: L	SYS PERF
** ******************** SUB-TECHNOLOGY: THRUSTER - GAS							
12060 40A01 A ACSHS	THRUST --- POUNDS --- IMPR. DIR: H	THROTLE RANGE --- NONE --- IMPR. DIR: H	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: STAR SENSOR - CHARGE COUPLED DEVICE (CCD)							
12060 50B01 A ACSHS	ACCURACY --- ARC-SECOND --- IMPR. DIR: L	SENSITIVITY --- VISUAL MAGNITUDE STAR --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- . IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: STAR SENSOR - IMAGE DISSECTOR							
12060 50B02 A ACSHS	ACCURACY --- ARC-SECOND --- IMPR. DIR: L	SENSITIVITY --- VISUAL MAGNITUDE STAR --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: EARTH SENSOR							
12060 50B03 A ACSHS	ACCURACY - LOW EARTH ORBIT --- DEGREES --- IMPR. DIR: L	ACCURACY - GEOSYNC ORBIT --- DEGREES --- IMPR. DIR: L	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP

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CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: SUN SENSOR - ANALOG							
12060 50B04 A	ACCURACY --- DEGREES --- IMPR. DIR: L	SENSING TECHNIQUE --- NONE --- IMPR. DIR: X	DETECTOR TYPE --- NONE --- IMPR. DIR: X	NUMBER OF AXIS --- 1 OR 2 --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
ACSHS							
** ******************** SUB-TECHNOLOGY: SUN SENSOR - DIGITAL							
12060 50B05 A	ACCURACY --- DEGREES --- IMPR. DIR: L	SENSING TECHNIQUE --- NONE --- IMPR. DIR: X	DETECTOR TYPE --- NONE --- IMPR. DIR: X	NUMBER OF AXIS --- 1 OR 2 --- IMPR. DIR: H	INTEGRATION TIME --- MILLISECONDS --- IMPR. DIR: L	--- --- IMPR. DIR:	COMP
ACSHS							
** ******************** SUB-TECHNOLOGY: CONTROL MOMENT GYRO - SINGLE GIMBAL							
12060 60A01 A	ANGULAR MOMENTUM --- FT-LB-SEC --- IMPR. DIR: H	TORQUE --- FT-LB --- IMPR. DIR: H	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
ACSHS							
** ******************** SUB-TECHNOLOGY: CONTROL MOMENT GYRO - DOUBLE GIMBAL							
12060 60A02 A	ANGULAR MOMENTUM --- FT-LB-SEC --- IMPR. DIR: H	TORQUE --- FT-LB/AXIS --- IMPR. DIR: H	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
ACSHS							
** ******************** SUB-TECHNOLOGY: REACTION WHEEL							
12060 60A03 A	ANGULAR MOMENTUM --- FT-LB-SEC --- IMPR. DIR: H	TORQUE --- INCH-OUNCES --- IMPR. DIR: H	LIFE --- YEARS --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
ACSHS							

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: GYROSCOPE - DRY TUNED												
10020 40A01 A ACSHS 17	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- OBTAINED FROM NASDA 85-86 BROCHURE SEE PAGE#:D	---- ---- ----	---- ---- ----	Y P RD U	.017 ----	.002 ----	----	100 ---- PPM (1 SIGMA)	----	----	JBI/01- 01-86/ 01/01/8 6 D003A 01/01/8 6 JA
10020 40A01 A ACSHS 43	C	NATIONAL SPACE AGENCY OF JAPAN (NASDA) ---- 4-1 HAMAMATSU-CHO 2-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	.03 ----	----	----	----	----	JCS/BRO CHURE / / D019A / / JA
10020 40A01 A ACSHS 102	E	NIPPON PRECISION CO. LTD. ---- ?, JAPAN ---- ---- ARTICLE DOES NOT INDICATE THE TYPE OF GYRO	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO GYRO-M ICROFL EX - MECHAN ICAL GYRO	----	----	----	----	----	JAX/#94 2/006 11/27/8 9 D046A / / JA
** ############### SUB-TECHNOLOGY: GYROSCOPE - RING LASER (RLG)												
10020 50A01 A ACSHS 86	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAJ/10- 25-89/0 02 10/25/8 9 D038A 02/01/8 9 JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
10020 50A01 A ACSHS 93	E	JAPAN AVIATION ELECTRONICS ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ---- ENTRY TO INDICATE ACTIVITY IN THIS TECHNOLOGY	---- ---- ----	---- ---- ----	Y U	---- SEE MEMO	----	----	----	----	----	JAU/MSG 2887-81 53/02 03/24/8 7 D040A / / JA
** ************** SUB-TECHNOLOGY: GYROSCOPE - FIBER OPTIC (FOG)												
10020 70A01 A ACSHS 28	E	OPTOELECTRON. TECHNOL. RES. CORP. c/o SHARP CORP. CENTRAL RES. LABS. ---- 2613-1 ICHINOMOTO TENRI NAARA 632 JAPAN ---- H.TAKIGUCHI, H.KUDO, S.KANEIWA, C.SAKANE ---- ALSO: T. HIJIKATA WAS INVOLVED	---- ---- ----	---- ---- ----	Y Y DT U	---- SEE MEMO	----	----	----	----	----	JBW/12- 06-87/0 788 12/06/8 7 D009A / / JA
10020 70A01 A ACSHS 84	E	OPTOELECTRONIC INDUSTRY & TECHNOLOGY DEVELOPMENT ASSOCIATION (OITDA) ---- ?, JAPAN ---- ---- OITDA HAS REPORTED TRENDS IN OPTICAL TECHNOLOGY WERE STUDIED SPECICALLY FIBER GYROSCOPES	---- ---- ----	---- ---- ----	N P RD U	---- SEE COMMEN TS ABOVE	----	----	----	----	----	JBB/10- 01-89/0 73 10/01/8 9 D036A / / JA

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10020 70A01 A ACSHS 85	E	HITACHI LTD. ---- 1-2 MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JBB/10- 01-89/0 146 10/01/8 9 D037A / / JA
10020 70A01 A ACSHS 96	E	UNIVERSITY OF TOKYO, RESEARCH CENTER FOR ADVANCED SCIENCE AND TECHNOLOGY ---- 4-6-1 KOMABA, MEGURO-KU, TOKYO 153, JAPAN ---- K.HOTATE & S.SAMUKAWA ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JEP/VOL 2 PT.2/03 97 01/27/8 8 D042A / / JA
10020 70A01 A ACSHS 97	E	MITSUBISHI ELECTRIC CORPORATION, CENTRAL RESEARCH LABORATORY ---- 8-1-1, TSUKAGUCHI-HONMACH I, AMAGASAKI, HYOGO, 661 JAPAN ---- M.TAKAHASHI, S.TAI, K.KYUMA & K.HAMANAKA ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JEP/VOL 2 PT.2/04 03 01/27/8 8 D043A / / JA
10020 70A01 A ACSHS 103	E	MITSUBISHI PRECISION COMPANY, LTD. ---- MITSUBISHI DENKI BLDG., 2-3, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JAX/#93 8/008 10/30/8 9 D047A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
10020 70A01 A ACSHS 99	B	JAPAN AVIATION ELECTRONICS (JAE) ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	.01 ---- SEE MEMO	----	----	----	----	----	JEOAD-A 189 294/2-4 2 05/01/8 7 D044B / / JA
** *************** SUB-TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT (CONT)												
12060 13A01 B ACSHS 24	E	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES ---- TOKYO 100, JAPAN ---- ---- SEE MEMO FOR SPACE BUSINESS PRODUCTLINE	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JAJ/07- 12-89/0 80 07/12/8 9 D005C / / JA
12060 10A01 B ACSHS 27	D	UNIVERSITY OF OSAKA PREFECTURE ---- OSAKA, JAPAN ---- Y. MUROTSU, H. OKUBO & F. TERUI ----	---- ---- ----	---- ---- ----	Y A DT U	0.42 - 22.85 ---- EXPERIMENTAL - USING EULER-BERNOULLI THEORY	----	----	----	----	----	JBU/VOL 12 # 2/0264 04/01/8 9 D008A / / JA
12060 10A01 B ACSHS 32	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- GEODETIC PAYLOAD	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JCI/BRO CHURE / / D013A 12/01/8 5 JA

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12060 10A01 B ACSHS 55	E	MITSUBISHI PRECISION CO., LTD. ---- 13-16, MITA 3-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- INERTIAL GUIDANCE INDICATED FOR ETS-6 BUT NO REFERENCE TO WHAT TYPE	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAA/VOL 3 #6/001 06/30/8 8 D027C 04/11/8 8 JA
12060 10A01 B ACSHS 67	E	FUJITSU LIMITED ---- 1015, KAMIKODANAKA, NAKAHARA-KU, KAWASKI 211, JAPAN ---- T. YAMASHITA, K.ISHIZAKA, & T. UCHIYAMA ---- SEE MEMO FOR JAPAN'S BASIC ATTITUDE CONTROL PLAN	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	----	----	----	JDG/VOL 25 #1/006 03/15/8 9 D031A / / JA
12060 10A01 B ACSHS 83	E	MASTSUSHITA RESEARCH INSTITUTE ---- TOKYO, JAPAN ---- ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA), TSUKUBA SPACE CENTER ---- IBARAKI, JAPAN ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JBB/10-01-89/0 33 10/01/8 9 D035A / / JA
12060 10A01 B ACSHS 87	E	NATIOANL SPACE DEVEVOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- GMS SPIN-S TABILI ZED SPACEC RAFT	----	----	----	----	----	JBE/MSG 18800/0 01 10/06/8 9 D039A / / JA

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12060 10A01 B ACSHS 88	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, KOJIMA & TOGASHI ---- SEE MEMO & PAGE#:D039C	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO -GMS-4	----	----	----	----	----	JBE/MSG 18800/0 04 10/06/8 9 D039B 09/06/8 9 JA
12060 10A01 B ACSHS 90	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI & KOJIMA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD Y	---- GMS-5 - SPIN STABIL IZED	----	----	----	----	----	JBE/MSG 18800/0 4 11/06/8 9 D039D 01/01/9 3 JA
12060 10A01 B ACSHS 91	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MIANTO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI & KOJIMA ---- SEE MEMO & PAGE#:D039F	---- ---- ----	---- ---- ----	Y P RD U	---- GMS-6 SPIN STABIL IZED POTENT IAL	----	----	----	----	----	JBE/MSG 18800/0 05 11/06/8 9 D039E / / JA
12060 10A01 B ACSHS 98	E	JAPAN AVIATION ELECTRONICS (JAE) ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ---- ARTICLE CONTAINS ONLY GENERAL INFORMATION AS TO JAE'S	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JEO/AD- A189 294/2-4 1 05/01/8 7 D044A / / JA

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12060 10A01 B ACSHS 101	E	TOHOKU UNIVERSITY, ENGINEERING FACULTY ---- SENDAI, JAPAN ---- H.HAYASAKA & S.TAKEUCHI ---- GENERAL ENTRY	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JES/12-30-89/G 9 12/30/8 9 D045A 12/18/8 9 JA
** *************** SUB-TECHNOLOGY: THRUSTER - GAS												
12060 40A01 A ACSHS 14	B	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- CS-3 COMMUNICATION SATELLITE	---- ---- ----	---- ---- ----	Y A FP U	05 ---- 20 NEWTONS	----	>=7 YEARS ----	----	----	----	JBH/03-01-86/0 29 03/01/8 6 D001A 01/01/8 6 JA
12060 40A01 A ACSHS 20	B	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	4.5 - 6.74 ---- 20-30 NEWTONS, ION THRUSTER, SPECIFIC IMPULE :<3000 SEC.	----	----	----	----	----	JBI/01-01-86/ 01/01/8 6 D003D 01/01/8 6 JA
12060 40A01 A ACSHS 22	E	NIPPON OIL AND FAT CO. LTD ---- TOKYO 100 JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE COMMENTS	----	----	----	----	----	JAJ/07-12-89/0 77 07/12/8 9 D005A / / JA

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12060 40A01 A ACSHS 23	E	NIPPON SUIYAKU KOGYO ---- ?, JAPAN ---- ---- COMPANY PRODUCTLINE	---- ---- ----	---- ---- ----	Y A FP U	---- SEE COMMENTS	----	----	----	----	----	JAJ/07-12-89/077 07/12/89 D005B / / JA
12060 40A01 A ACSHS 26	B	INSTITUTE OF SPACE AND ASTRONAUTIACAL SCIENCES ---- 4-6-1 KOMABA, MEGURO-KU, TOKYO 153, JAPAN ---- R. AKIBA & K. UESUGI ----	---- ---- ----	---- ---- ----	Y P RD U	5.17 ---- THE ATTITUDE AND ORBITAL CONTROL MANUEVERS ARE CARRIED OUT BY A rEACTION cONTROL SUBSYSTEM (RCS) WHICH HAS EIGHT 23 NEWTON THRUSTERS AND FOUR 3 NEWTON THRUSTERS	----	----	----	----	----	JBT/VOL1/0281 10/26/86 D007A / / JA

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12060 40A01 A ACSHS 29	C	MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- 3-2, KASUMIGASEKI 1-CHOME, CHIYODA-KU, TOKYO 184, JAPAN ---- RADIO REGULATORY BUREAU ----	MINISTRY OF POSTS AND TELECOMMUNICATIONS ---- 2-1, NUKUI-KITAMACHI 4-CHOME, KOGANEI-SHI, TOKYO 184, JAPAN ---- RADIO RESEARCH LABORATORIES ----	---- ---- ----	N A FP U	---- ZERO-MOMEMTUM WHEELS AND HYDRAZINE THRUSTERSIN ALL THREE AXIS	----	03 ----	----	----	----	JCG/ITEM 4/003 / / D010A / / JA
12060 40A01 A ACSHS 41	E	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, 33-1, SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- 3 N THRUSTER x 6, N2H4 FUEL	----	----	----	----	----	JCR/MST5 SAT./001 01/05/85 D018B 01/08/85 JA
12060 40A01 A ACSHS 46	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	NEC CORPORATION ---- NEC BUILDING, 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- GMS-3 PRIME CONTRACTOR	---- ---- ----	Y A FP U	01.0004 ---- 4.45 NEWTONS GM3-3 SATELLITE PROPELLANT HYDRAZINE, 3 TANKS, 2 AXIAL AND 4 RADIAL THRUSTERS	----	05 ----	----	----	----	JCT/GMS-3 BROCHURE / / D020C 01/01/84 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 40A01 A ACSHS 75	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- MOS-1 SATELLITE SEE PAGE#-D021B, D021C, D021D	---- ---- ----	---- ---- ----	N A FP U	---- RCS-HY DRAZIN E MONO-P ROPELL ENT PROPUL SION SCHEME 1N THRUST ER X 4 PROPEL LENT TANK x 2	----	02 ----	----	----	----	JCU/02-01-87/0 06 02/01/8 7 D021A 02/18/8 7 JA
12060 40A01 A ACSHS 49	B	ISHIKAWAJIMA-HSRIM A HEAVY INDUSTRIES (IHI), SPACE DEVELOPMENT DIVISION ---- 6-2, MARUNOUCHI 1-CHOME, CHIYODA, TOKYO 100, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	0.214 - .072 ---- 1N THRUST ER THRUST RANGE .95-.3 2	---- SEE MEMO	----	----	----	----	JCY/IHI BROCHUR E/026 05/01/8 7 D023A 01/01/8 2 JA
12060 40A01 A ACSHS 52	E	ISHIKAWAJIMA-HARIM A HEAVY INDUSTRIES CO., LTD. ---- 2-2-1, OHTEMACHI, CHIYODA-KU, TOKYO 100, JAPAN ---- K.SHIINA, H.SUZUKI, K.UEMATSU, T.OHTSUKA ----	INSTITUTE OF SPACE & ASTRONAUTICAL SCIENCE ---- 3-1-1, YOSHINODAI, SAGAMIHARA-SHI, KANAGAWA 229, JAPAN ---- K. TOKI, Y. SHIMIZU & K. KURIKI ----	---- ---- ----	Y A DT U	---- SEE MEMO 50mN/k W	----	----	----	----	----	JCZ/16T H ISIS/00 1 05/22/8 8 D026A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	MESTPHSE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 40A01 A ACSHS 59	C	NATIONAL SPACE DEVELOPMENT AGENY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	MITSUBISHI ELECTRIC CORPORATION ---- MITSUBISHI DENKI BLDG., 2-3 MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y A FP U	04.496 ----	----	>=1.5 ----	----	----	----	JDA/ETS-V BROCHURE 06/01/87 D028D / / JA
12060 40A01 A ACSHS 64	D	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHOR NOT IDENTIFIED IN THIS ARTICLE	---- ---- ----	---- ---- ----	Y P RD U	---- ELETRO-THERMAL HYDRAZINE THRUSTER	----	10 ----	----	----	----	JDE/10-01-89/031 10/01/89 D030B 01/01/93 JA
12060 40A01 A ACSHS 89	C	NATIONAL SPACE DEVLOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI & KOJIMA ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	05 ----	----	----	----	JBE/MSG 18800/004 10/06/89 D039C 09/06/89 JA
12060 40A01 A ACSHS 95	D	OSAKA UNIVERSITY ---- TOYONAKA, OSAKA 560, JAPAN ---- H.TAHARA, Y.KAGAYA, T.YOSHIKAWA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JEM/VOL5 #6/0713 12/01/89 D041A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ************** SUB-TECHNOLOGY: STAR SENSOR - CHARGE COUPLED DEVICE (CCD)												
12060 50B01 A ACSHS 48	C	NEC CORPORATION - SPACE DEVELOPMENT DIVISION, YOKOHAMA PLANT ---- 4035, IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	012 ---- SEE MEMO FOR ADDITI ONAL SPECIF ICATIO NS	06 ----	----	----	----	----	JCW/BRO CHURE/0 01 05/01/8 5 D022A 02/01/8 7 JA
12060 50B01 A ACSHS 63	E	UNKNOWN ---- ---- ---- SOLAR A HAS A STAR TRACKER BUT NO OVERT EVIDENCE IF CCD OR IMAGE DISSECTOR	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JDE/10-01-89/0 18 10/01/8 9 D030A 08/01/9 1 JA
12060 50B01 A ACSHS 69	B	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO FOR OTHER SPECIFICATIONS	---- ---- ----	---- ---- ----	Y A FP U	---- ACCURA CY - 0.05 DEGREE S	6.0 ----	----	----	----	----	JDJ/BRO CHURE/0 03 / / D033A / / JA
** ************** SUB-TECHNOLOGY: STAR SENSOR - IMAGE DISSECTOR												
12060 50B02 A ACSHS 35	E	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, 33-1, SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- STAR SENSOR - N SLIT TYPE	----	----	----	----	----	JCP/01-05-85/0 01 01/05/8 5 D016A 02/20/8 3 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 50B02 A ACSHS 40	E	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, 33-1, SHIBA-GOCHOME, MINATO-KU, TOKYO 108 ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SOLAR SENSOR	----	----	----	----	----	JCR/ MS-T5 SAT/001 01/05/8 5 D018A 01/08/8 5 JA
12060 50B02 A ACSHS 54	E	TOSHIBA CORPORATION ---- 1-1, NIHONBASHI-MUROMAC HI, CHUO-CHO, TOKYO 103, JAPAN ---- ---- ARTICLE REFERS TO A SOLAR SENSOR WITH NO CLEAR INDICATION TO TYPE. SEE PAGE#: D027C	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAA/VOL 3 #6/001 06/30/8 8 D027B 04/11/8 8 JA
12060 50B02 A ACSHS 70	C	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	060 ---- PHOTOM ULTIPI ER TUBE USED AS DETECT OR	----	----	----	----	----	JDJ/BRO CHURE/0 01 / / D033B / / JA
12060 50B02 A ACSHS 71	C	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	060 ---- 1 ARC MIN, DETECT OR - PHOTOM ULTIPL IER TUBE	04 ----	----	----	----	----	JDJ/BRO CHURE/0 02 / / D033C / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 50B02 A ACSHS 82	D	HAMAMATSU PHOTONICS K.K. ---- 1126, ICHINO-CHO, HAMAMATSU CITY, 435, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y	----	----	----	----	----	----	JCC/09-01-89/0 04 09/01/8 9 D034A / / JA
** ############### SUB-TECHNOLOGY: EARTH SENSOR												
12060 50B03 A ACSHS 15	B	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- CS-3 COMMUNICATION SATELLITE	---- ---- ----	---- ---- ----	Y A FP U	0.2 ---- HALE CONE ANGLE	----	----	----	----	----	JBH/03-01-86/0 27 03/01/8 6 D002A 01/01/8 6 JA
12060 50B03 A ACSHS 19	B	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- OBTAINED FROM 85-86 NASDA BROCHURE	---- ---- ----	---- ---- ----	Y A FP U	.03 ----	.03 ----	----	----	----	----	JBI/01-01-86/ 01/01/8 6 D003C 01/01/8 6 JA
12060 50B03 A ACSHS 74	E	MITSUBISHI ELECTRIC CORPORATION (MELCO) ---- 2-3, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100 JAPAN ---- ---- INFORMATION ENTRY- ARTICLE INDICATES MITSUBISHI MAKES EARTH SENSORS BUT TYPE NOT INDICATED	---- ---- ----	---- ---- ----	N A FP U	---- SEE COMMEN TS	----	----	----	----	----	JCK/PAGE 005 / / D014A / / JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 50B03 A ACSHS 45	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	NEC CORPORATION ---- NEC BUILDING, 33-1 SHIBA 2-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- GMS-3 PRIME CONTRACTOR	---- ---- ----	Y A FP U	---- see memo	----	----	----	----	----	JCT/GMS -3 BROCHUR E / / D020B 01/01/8 4 JA
12060 50B03 A ACSHS 51	E	NATIONAL SPACE DEVELOPMET AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 108, JAPAN ---- YUJI MIYACHI & YASUSHI HORIKAWA ----	NASDA LOS ANGELES OFFICE ---- 300 SOUTH GRAND AVE., SUITE 2760, LOS ANGELES, CA. 90071 ---- YOSHIKAZU KAMIYA ----	---- ---- ----	Y P RD U	---- ERS-1 SEE MEMO	----	----	----	----	----	JBT/VOL III/162 5 / / D024A 01/01/9 1 JA
12060 50B03 A ACSHS 53	E	NEC CORPORATION ---- NEC BUILDING, 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAA/VOL 3 #6/001 06/30/8 8 D027A 04/11/8 8 JA
** ############### SUB-TECHNOLOGY: SUN SENSOR - ANALOG												
12060 50B04 A ACSHS 16	E	NATIONAL SPACE DEVELPOMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- CS-3 COMMUNICATION SATELLITE	---- ---- ----	---- ---- ----	Y A FP U	---- SUN SENSOR	----	----	----	----	----	JBH/03- 01-86/0 27 03/01/8 6 D002B 01/01/8 8 JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 50B04 A ACSHS 18	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- OBTAINED FROM 85-86 NASDA BROCHURE	---- ---- ----	---- ---- ----	Y A FP U	---- .02 ESTIMATED ACCURACY, FIELD OF VIEW +- 32 DEG x +-32 DEG	----	----	----	----	----	JBI/01-01-86/ 01/01/86 D003B 01/01/86 JA
12060 50B04 A ACSHS 72	E	MITSUBISHI ELECTRIC CORPORATION (MELCO) ---- 2-3, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION ENTRY- MITSUBISHI MAKES SUN SENSORS BUT NO OTHER INFORMATION GIVEN	---- ---- ----	---- ---- ----	N A FP U	---- SEE COMMENTS ABOVE	----	----	----	----	----	JCK/PAGE 005 / / D014B / / JA
12060 50B04 A ACSHS 38	E	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SUN SENSOR - SPIN AND NON SPIN TYPE	----	----	----	----	----	JCO/SAT #9/001 / / D017A 02/14/84 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 50B04 A ACSHS 44	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASADA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	NEC CORPORATION ---- NEC BUILDING, 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- PRIME CONTRACTOR	---- ---- ----	Y A FP U	---- SUN SENSOR	----	----	----	----	----	JCT/GMS -3 BROCHUR E / / D020A 01/01/8 4 JA
12060 50B04 A ACSHS 73	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	---- MOS -1 SUN SENSOR - TYPE OF SUNSEN SOR NOT INDICA TED	----	----	----	----	----	JCU/02-01-87/0 06 02/01/8 7 D021B 02/18/8 7 JA
12060 50B04 A ACSHS 56	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHU, MINATO-KU, TOKYO 105, JAPAN ---- ----	MITSUBISHI ELECTRIC CORPORATION ---- MITSUBISHI DENKI BLDG., 2-3 MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JDA/ETS -V BROCHUR E 06/01/8 7 D028A / / JA
12060 50B04 A ACSHS 78	B	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	01.5 DEG ----	COSINE LAW ----	SILICO N SOLAR CELL ----	----	----	----	JDJ/BRO CHURE/0 07 / / D033F / / JA

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CTL # / SHEET / CODE / REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	MESTPHSE	PAR 1 VALUE / NOTES	PAR 2 VALUE / NOTES	PAR 3 VALUE / NOTES	PAR 4 VALUE / NOTES	PAR 5 VALUE / NOTES	PAR 6 VALUE / NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 50B04 A ACSHS 81	D	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN' ---- ----	---- ---- ----	---- ---- ----	Y A FP U	05 ----	COSINE LAW ----	SILICO N PHOTO CELL ----	----	----	----	JDJ/BRO CHURE/0 08 / / D0331 / / JA
** *************** SUB-TECHNOLOGY: SUN SENSOR - DIGITAL												
12060 50B05 A ACSHS 77	C	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	01.5 ----	V-SHAP ED SLIT ----	SILICO N SOLAR CELL ----	----	----	----	JDJ/BRO CHURE/0 05 / / D033E / / JA
12060 50B05 A ACSHS 80	B	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN' ---- ----	---- ---- ----	---- ---- ----	Y A FP U	0.05 ----	LINEAR CCD+SL IT ----	2048 ----	2 ----	7.9 ----	----	JDJ/BRO CHURE/0 08 / / D033H / / JA
12060 50B05 A ACSHS 79	B	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	----	LINEAR CCD+SL IT ----	2048 PIXCEL L ----	2 ----	----	----	JDJ/BRO CHURE/0 08 / / D033G / / JA
** *************** SUB-TECHNOLOGY: CONTROL MOMENT GYRO - SINGLE GIMBAL												
12060 60A01 A ACSHS 37	D	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	04.26 ---- 5.8Nms (2,000 RPM)	----	----	----	----	----	JCP/01-05-85/0 01 01/05/8 5 D016C 02/20/8 3 JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 60A01 A ACSHS 42	D	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, 33-1 SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	14.7 ---- 20 Nms ATE 2000 RPM	----	----	----	----	----	JCR/MS- T5 SAT./00 1 01/05/8 5 D018C 01/08/8 5 JA
** *************** SUB-TECHNOLOGY: CONTROL MOMENT GYRO - DOUBLE GIMBAL												
12060 60A02 A ACSHS 34	D	NATIONAL AEROAPCE LABORATORY ---- 1880 JINDAIJI-MACHI, CHOFU-SHI, TOKYO 182, JAPAN ---- DR CHIKARA MURAKAMI ----	MITSUBISHI ELECTRONICS CORPORATION ---- 2-3, MARUNOUCHI 2 CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y A DT U	051.47 ---- 70 Nms	----	----	----	----	----	JCM/PAG E 004 / / D015B / / JA
12060 60A02 A ACSHS 39	D	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	14.007 ---- 19.05 Nms (2000 RPM)	----	----	----	----	----	JCQ/ SAT. #9/001 / / D017B 02/14/8 4 JA
12060 60A02 A ACSHS 47	E	NATIOANL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	---- MOS-1	----	----	----	----	----	JCU/02- 01-87/0 06 02/01/8 7 D021D 02/17/8 7 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
12060 60A02 A ACSHS 58	D	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	MITSUBISHI ELECTRIC CORPORATION ---- MITSUBISHI DENKI BLDG., 2-3 MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	>=1.5 ----	----	----	----	JDA/ETS-V BROCHURE 06/01/87 D028C / / JA
12060 60A02 A ACSHS 65	A	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHOR NOT INDICATED IN THIS ARTICLE	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	10 ----	----	----	----	JDE/10-01-89/031 10/01/89 D030C 01/01/93 JA
12060 60A02 A ACSHS 66	C	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHOR NOT INDICATED IN THIS ARTICLE	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	3 ----	----	----	----	JDE/10-01-89/035 10/01/89 D030D / / JA
12060 60A02 A ACSHS 92	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI & KOJIMA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P DT U	---- GMS-6 3-AXIS	----	----	----	----	----	JBE/MSG18800/005 11/06/89 D039F / / JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: REACTION WHEEL												
12060 60A03 A ACSHS 33	D	NATIONAL AEROSPACE LABORATORY ---- 1880 JINDAIJI-MACHI, CHOFU-SHI, TOKYO 182, JAPAN ---- DR. CHIKARA MURAKAMI ----	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	Y A DT U	05.5 ---- +-7.5 Nms	----	----	----	----	----	JCM/PAG E 003 / / D015A / / JA
12060 60A03 A ACSHS 68	D	NAL ---- 1880, JINDAIJI-MACHI, CHOFU-SHI, TOKYO 182, JAPAN ---- CHIKARA MURAKAMI & ATSUHI NAKAJIMA ---- REPORTED IN 1984	TOSHIBA R & D CENTER ---- 4-1, UKISHIMA-CHO, KAWASKI-KU, KAWASKI 210, JAPAN ---- SHITTA SHINGU & YOSHIHARU SHIMAMOTO ----	---- ---- ----	Y A FP U	05.51 ---- 2-AXIS CONTRO LLED	----	----	----	----	----	JDI/ABS TRACT/6 47 / / D032A / / JA

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TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: GYROSCOPE - DRY TUNED												
10020 40A01 A D019A ACSHS 31	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 4-1 HAMAMATSU-CHO, 2-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- M.MOCHIZUKI, E.SOGAME & Y.SHIBATO ---- H-I LAUNCH VEHICLE - TUNED PLATFORM GYROS SEE PAGE# D019A	---- ---- ----	---- ---- ----	N A FF U	---- SEE COMMEN TS ABOVE	----	----	----	----	----	JCN/10- 10-87/0 01 10/10/8 7 D012A 08/27/8 7 JA
** *************** SUB-TECHNOLOGY: GYROSCOPE - RING LASER (RLG)												
10020 50A01 A D038A ACSHS 21	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO FOR INFO.	---- ---- ----	---- ---- ----	Y A DT	----	----	----	----	----	----	JAX/VOL 3 #23/037 08/01/8 7 D004A / / JA
10020 50A01 A D038A ACSHS 25	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- TOKYO, JAPAN ---- ---- H-II LAUNCH VEHICLE	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JAX/VOL 7 # 27/022 09/02/8 8 D006A 01/01/9 2 JA

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TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
10020 50A01 A D038A ACSHS 30	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 4-1 HAMAMATSU-CHO, 2-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- M. MOCHIZUKI, E.SOGAME AND Y.SHIBATO ---- H-II LAUNCH VEHICLE	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JCN/10-17-87/0 318 10/10/8 7 D011A 01/01/8 7 JA
10020 50A01 A D040A ACSHS 104	E	JAPAN AVIATION ELECTRONICS ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ---- GENERAL INFORMATION WITH NO PARAMETER VALUES GIVEN	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	----	----	JEO/AD-A189294 /2-41 05/01/8 7 D044B / / JA
** *************** SUB-TECHNOLOGY: GYROSCOPE - FIBER OPTIC (FOG)												
10020 70A01 A D044B ACSHS 94	E	JAPAN AVIATION ELECTRONICS ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ---- ENTRY TO INDICATE ACTIVITY IN THIS TECHNOLOGY	---- ---- ----	---- ---- ----	Y U	----	----	----	----	----	----	JAU/MSG -2887-8 153/02 03/24/8 7 D040B / / JA
10020 70A01 A D044B ACSHS 100	C	JAPAN AVIATION ELECTRONICS (JAE) ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A PP U	0.1-10 ---- SEE MEMO	----	----	----	----	----	JEO/AD-A189 294/2-4 2 05/01/8 7 D044C / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
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TECHNOLOGY: ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: THRUSTER - GAS												
12060 40A01 A D023A ACSHS 50	B	ISHIKAWAJIMA-HARIM A HEAVY INDUSTRIES (IHI), SPACE DEVELOPMENT DIVISION ---- 6-2, MARUNOUCHI 1-CHOME, CHIYODAKU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	4.4 - 1.4 ---- 20N THRUST ER, THRUST RANGE 19.6 - 6.2 N	----	----	----	----	----	JCY/IHI BROCHUR E/025 05/01/8 7 D023B 01/01/8 5 JA
12060 40A01 A D026A ACSHS 62	E	ISHIKAWAJIMA-HARIM A HEAVY INDUSTRIES CO., LTD. ---- 1-6-2, MARUNOUCHI, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JDC/BRO CHURE/0 01 / / D029A 03/01/8 0 JA
** *************** SUB-TECHNOLOGY: STAR SENSOR - IMAGE DISSECTOR												
12060 50B02 A D016A ACSHS 36	E	NEC CORPORATION, SPACE DEVELOPMENT DIVISION ---- NEC BUILDING, 331, SHIBA-GOCHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SOLAR SENSOR - SPIN TYPE AND NON-SP IN SOLAR SENSOR	----	----	----	----	----	JAP/01- 05-85/0 01 01/05/8 5 D016B 02/20/8 3 JA
** *************** SUB-TECHNOLOGY: EARTH SENSOR												
12060 50B03 A D021A ACSHS 76	D	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ---- MOS-1 EARTH SENSOR	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	----	----	JCU/02- 01-87/0 06 02/01/8 7 D021C 02/18/8 7 JA

ecord# PAGENO DESCRAPPLC
3 D000C

GYROSCOPE -FLOATED

Most spacecraft have an inertial (or stabilized) platform that consists primarily of three gyroscopes oriented along 3 orthogonal axes. The purpose of this platform is to sense any change in attitude of the spacecraft using the gyros as sensing elements. While some pointing sensor provides the initial attitude reference these gyros provide a continual internal reference that senses any change in attitude and reports it to the attitude control electronics system. The usual arrangement is to provide periodic updates from the pointing sensor but to have the platform remember the attitude reference between updates and when the external reference from the pointing sensor may be unavailable.

Gyroscopes obey the same law of angular momentum that keeps any rotating body balanced and pointing at a fixed attitude in inertial space. A two-axis position gyro (one that senses position rather than rate) can be made by mounting a wheel on a low friction bearing and spinning it at high speed by an electric motor. The speed should be between 10 and 50 thousand revolutions per minute (RPM) so that the small light wheel will generate adequate angular momentum. If this spinning wheel is mounted on gimbals, it will remain pointing in a constant direction even if the outer gimbal case is rotated. An angle transducer mounted between the gyro and gimbal would measure this change in attitude.

However, this simple position gyro would be subject to large drift errors, caused in part by the large angles possible for the gimbal axis. Accordingly, the rate gyro is a more accurate device for measuring small attitude rate changes. In its simplest form, it is a single-axis gyro in which springs are used to keep the gimbal axis at the zero position. A rotation of the outer case causes a rotation of the gimbal proportional to the angular rate (rather than the magnitude) of the rotation. The movement of the gimbal axis is limited by the springs, which reduces drift errors. If the springs are replaced by a servomechanism (called a torquer) that drives the gimbal angle toward zero, then the current applied to the gimbal-drive torquer motor is proportional to the rate of rotation. This form of the rate gyro is the most common in spacecraft attitude control systems. The rate signal can also be integrated electronically to also derive a measure of the angular position, in the "rate integrating gyro". In the most modern gyros, this error signal from the gimbal is digital and the torquer is driven by small precise current pulses that are counted to derive the rate information.

A "floated" gyro incorporates a hydrocarbon fluid (with a high specific gravity) to float all or part of the gimbal mass, so as to unload the gimbal bearings, serve as a bearing lubricant and a damping medium. The inaccuracies that are caused by irregular and unpredictable variations in bearing friction are minimized by reducing the gimbal bearing loads.

4 D0000

GYROSCOPE - DRY TUNED

This is a two-degree-of-freedom, free-rotor gyro consisting of a wheel, a motor, a flexible support joining the two, a spring

compensating mechanism, and two sets of torquers and pickoffs. Freeing the rotor from restraints by suspending it on a flexure joint is the purpose underlying this design, and is accomplished by separating the rotor drive from the rotor sensor. Spring restraint of the flexure joint suspension is compensated by electromagnetic means.

Because there are no pigtails, flotation fluids or jeweled supports, the design is inherently simple, and contributes substantially to cost reduction while increasing reliability. Performance capabilities make this device competitive with fluid floated gyros.

The elimination of a flotation fluid has provided a substantial reduction in thermal sensitivity. The Singer Corporation produces these gyros under the name of Gyroflex.

17 D003A

Research and Development

Satellite Technology

Study on satellite technology is advancing in the area of three-axis stabilized geostationary satellites. Research is in progress on high accuracy attitude control systems (fine sun sensor, fine earth sensor, etc.), propulsion system (ion thruster), electric power system (long life high capacity battery, long life lightweight paddle mechanism, etc.).

In addition, research is also in progress on platforms and free flying vehicles.

31 D012A
43 D019A

H-I ROCKET

A. Characteristics of Inertial Guidance Equipment

1. Type	4 Gimbal Axis Platform
2. Alignment Type	Gyro Compassing self alignment
3. Alignment Accuracy	
* Level	1 min. or less
* Azimuth	6 min. or less
4. Fixed Restraint Drift	.03 deg/hr

B. Inertial Guidance Computer

1. Control Type	Microprogam Control Type
2. Arithmetic	Fixed Point
3. Memory	16 kW
4. Word Length	16 Bits
5. Computation Lines (usec)	
* Add	3.7
* Mpy	9.2
* Div	11.6

102 D046A

BAe TO OFFER AIRCRAFT EQUIPMENT TECHNOLOGY TO JAPAN

British Aerospace (BAe) of the U.K. will offer its manufacturing technology or aircraft equipment to Japanese manufacturers. First of all, BAe has tied up with Nippon Precision Co., Ltd. which will produce BAe gyro, a core of an inertial navigation system, under license.

BAe has promoted aircraft equipment sales to Japan by exports only. Now, allowing license production by Japanese manufacturers, BAe is expected to strengthen its aircraft business in the Japanese market. In particular, it plans to promote sales to the Defense Agency (JDA).

Nippon Precision will manufacture a mechanical gyro called Microflex which is 25 mm in length and 22 mm in diameter. It is said to be the world's smallest gyro.

Nippon Precision plans to start the license production within this year and manufacture 100-200 units a year. The company hopes to install the gyro in missiles and space equipment as well as the 75-seat commercial transport that MITI plans to develop under an international joint program.

Nippon Precision has been tied up with Sanders Associates of the U.S. and has manufactured gyros for short-range surface-to-air missiles under license since 20 years ago. Through the tie-up with BAe, the company is expected to expand the range of its products.

7 D0000

GYROSCOPE -RING LASER

The ring-laser gyroscope (RLG) is one type of optical gyroscope that is being developed for spacecraft applications. The optical gyro's greater reliability, wide dynamic range and ability to withstand high-g's and harsh environments make them superior to mechanical gyroscopes. These advantages are compounded by the compact size and lightweight nature of optical gyros. Optical based systems are insensitive to gravitational fields and their output is highly linear over a very large dynamic range. Other advantages of optical gyros include maintenance-free operation, low cost, ruggedness and instant availability (rotor spin-up is eliminated). Accuracy of optical gyros have not reached the level of high-quality mechanical systems but they have excellent development potential.

The RLG uses three or four mirrors in a glass block forming a gas laser cavity. Laser beams are sent around the closed triangular or square path. Two laser beams traveling in opposite directions will return to their point of origin at the same time when the cavity ring is stationary. If, however the ring is rotating there will be a very minute shift in the arrival times of the two beams caused by a difference in path length. This slight change in path length changes the effective length of the cavity and its resonant frequency. This shift in resonant frequency is used to measure ring rotation.

The RLG is a very specialized opto-mechanical instrument requiring extremely close manufacturing tolerances and a clean room environment. Small RLGs may have limited shelf life due to slow leakage of the helium-neon lasing gas mixture.

RLGs are currently being installed as standard equipment on the Boeing 757, 767, and Airbus 310. They are also being actively evaluated for a variety of next generation military systems. Significant advances were made in the quality of low loss mirrors in order to make this possible. Mirror coating and polishing technology has improved enough to make absorption and backscatter losses minimal.

Manufacturers are currently divided over the three-mirrored

triangle and four-mirrored square designs. Three-mirror proponents such as Honeywell Inc. and Sperry Corp., argue that fewer mirrors mean lower losses, fewer faces to polish and lower production costs. Four-mirror proponents such as Litton and Rockwell argue that since backscatter and absorption are less at a 45 degree angle of incidence, four mirrors can have the same losses but less backscatter than three-mirrored designs. The square RLG has a greater sensitivity, since the ratio of configuration area to perimeter length is inherently larger.

It appears likely that at least for multiaxis systems the square light path will be favored. Future three-in-one axis designs will almost certainly be made from a single block. It is much easier to machine three square rings in one block than three triangles. A cube with a mirror at the center of each face uses only six mirrors for all three orthogonal axis rings . The glass ceramic most widely used to machine the basic RLG housing is Zerodur made in Germany. This glass has a low thermal expansion coefficient, is readily machinable and is a good helium barrier. Nuclear hardening capability is a more recent concern. If the glass becomes opaque when exposed to high levels of nuclear radiation, the light intensity transmitted through the output mirror could fall below detection levels.

The RLG can lose information at low rotational rates because the counter-rotating waves tend to remain locked at a common frequency because the system behaves as two coupled oscillators. Two common practices are used to avoid this lock-in, one is to angularly dither the gyro cavity about the input axis and the second is to optically bias the laser so the two frequencies are unequal in the absence of rotation. Both of these methods require further development to optimize RLG performance.

21 D004A

The H-II rocket will use a strap-down inertia guidance system which will consist of an inertial measurement unit (IMU), inertial guidance computer (IGC), data interface unit(DIU), electronics package(E-PKG), lateral acceleration measurement unit (LAMU) and inertial guidance program(IGP). The system will navigate, guide, and control attitude, flight sequence and the propulsion system tank pressure. The intended system accuracy is 250km for apogee latitude errors and 0.03 degrees for orbital inclination errors (on transfer orbit) in geostationary missions and 20km for orbital errors, 0.03 degrees for orbital inclination for sun synchronous missions. In designing and developing the system, consideration has to be given to smallness, lightness, accuracy, power consumption, reliability and resistance to the space environment.

A preliminary test for a guidance system was conducted last year. In the light of the results, basic design work is in progress. For the preliminary design, a breadboard model (BBM) was made and a system interface test, using this model, was conducted to confirm its functions. The development of electronic and electric pads, such as semiconductors, connectors and laser gyro mirrors, for the guidance equipment has been started.

The design, manufacture and evaluation testing of an engineering model (EM) is also under way. The functions, performance and environmental resistance characteristics of each piece of equipment will be evaluated. In addition, night simulation and airborne tests are planned to confirm the

functions of the in-flight rocket guidance control system. The facilities and software necessary for these tests are now under development.

The laser gyro, the most critical element in the guidance equipment, has been undergoing development since 1987 and an EM test is now being conducted. As a result, Japan now has the ability to develop a space laser gyro by itself.

25 D006A

Guidance/Control System

Unlike the H-I which employs a stable platform unit, the H-II will use a new guidance/control system using a strapdown inertial measurement unit (IMU) with three ring laser gyros. The system consists of the IMU, a guidance computer, a data interface unit, control electronics packages, and a lateral acceleration measurement unit (LAMU). Lateral acceleration feedback control using the LAMU will be applied to relieve aerodynamic loads during the first phase of night.

These components will be installed on a platform located at the top of the second stage, called the guidance section, and in the inter-stage. They will control the orbit and altitude of payloads until such time as they are Jettisoned from the second stage, thereby enabling highly accurate insertion into orbit.

Using a breadboard model, combined tests of the IMU and the guidance computer with an inertial guidance program were conducted in early 1987, and the interface between hardware and software verified. Tests of the guidance/control system including the use of an airplane began this July, and will be completed in 1989.

30 D011A

H-II LAUNCH VEHICLE - Ring Laser Gyro

A breadboard model of the guidance system was manufactured and the design for an engineering model was performed last year. In 1988 the engineering model will be manufactured and tested. Software, the inertial guidance program is under development.

86 D038A

H-II Rocket Inertial Guidance Device Tested

From July, 1988 to the beginning of February this year, NASDA carried out a system experiment of a technical experimental model of the H-II rocket inertial guidance device at the Tsukuba Space Center and ended with the required objectives achieved.

The inertial guidance device consists of an inertial sensor unit, an inertial guidance computer, an inertial guidance program, a data interface unit, an electronic controller, and a lateral acceleration measurement device. The design and test manufacture experiments of the technical experiment model have been carried out since 1986, and the system test is being carried out as part of that evaluation.

The objective of the system test is the acquisition of data which will be reflected in the confirmation of its function as an inertial guidance device, the confirmation of its suitability as an interface among equipment, the design and manufacture of

final equipment stage.

(1) Simple test: the simple test will confirm the basic function and performance, and conductivity and insularity, at the simple level of the hardware equipment.

(2) Hard assembly test: This test will conduct the timing of the interface signal when the various equipments are assembled and the measurement of the voltage level, and the confirmation of the data transfer function.

(3) Soft/hard assembly test: This test will conduct the confirmation of the function when the inertial guidance program and the hardware equipment are assembled, and the measurement of the period of the inertial guidance program.

(4) System integration test: This test will carry out a flight simulation by combining all the hardware equipment and the inertial guidance problem, and will confirm the guidance control function in the inertial guidance device.

An especially important aspect of the system integration test is that it will confirm the initial alignment function by means of the inertial guidance program and that it will confirm the strap-down navigational guidance function by a signal from a laser gyro, which is the output of the inertial sensor unit. Consequently, the former simulated the movement of the rocket at the point of firing by carrying an inertial sensor unit in an oscillation test device. Moreover, the latter conducted tests of the inertial sensor unit on top of the eight table by causing night simulated movement at the propelled flight phase of the rocket, its initial flight phase, and its spin phase.

The results of the tests obtained the confirmation of the guidance control function of the inertial guidance device and the suitability of the interfaces among the various pieces of hardware of the inertial guidance equipment and between the hardware and the software. These results have been provided for the design of the prototype model that is currently moving forward and the test and operation of the rocket at the assembly plant and the launch site. following these test, preparations are being made in anticipation of carrying out a system test (flight) in May which will carry the inertial guidance device on board an aircraft.

93 D040A

JAPAN AVIATION ELECTRONICS

JAE WORKS EXTENSIVELY ON LASER INERTIAL NAVIGATION SYSTEMS, LASER GYROS, AND FIBER OPTIC GYROS. JAE'S RING LASER GYRO CLOSELY FOLLOWS THAT WHICH IS BEING DONE AT HONEYWELL.

104 D044B
8 D000O

GYROSCOPE - FIBER OPTIC

The fiber-optic gyroscope (FOG) is one type of optical gyroscope

that is being developed for spacecraft applications. The optical gyro's greater reliability, wide dynamic range and ability to withstand high-g's and harsh environments make them superior to mechanical gyroscopes. These advantages are compounded by the compact size and lightweight nature of optical gyros. Optical based systems are insensitive to gravitational fields and their output is highly linear over a very large dynamic range. Other advantages of optical gyros include maintenance-free operation, low cost, ruggedness and instant availability (rotor spin-up is eliminated). Accuracy of optical gyros have not reached the level of high-quality mechanical systems but they have excellent development potential.

The most advanced Fiber Optic Gyroscope (FOG) uses a long optical fiber that is coiled around a central axis to detect path length shifts induced by rotation about the central axis. The fiber length is being pushed to distances of one kilometer because the differences in path length are directly proportional to rotational speed and travel time. The longer fiber lengths facilitate rotation measurements but optic qualities of the fiber limit total length of the coil winding. A beam splitter is used to direct two light beams through the fiber-optic coil in opposite directions. The light exiting the system is measured by sophisticated electronic techniques to obtain the rate of rotation.

Fiber-optic gyros, in comparison to ring-laser gyros, appear to have a clear advantage with respect to weight, size, and packaging flexibility (the fiber-optic coil may be remotely mounted), and FOGs are solid state devices which are not sensitive to shelf life. Also, because the FOG is a solid state device, it will have a significant cost advantage over RLGs as mass production of key elements matures.

Fiber-optic gyro technology is comparatively new; the first laboratory demonstration models were reported in 1976. Companies pursuing fiber-optic gyro technology have included: McDonnell Douglas, Litton, Standard Electric Lorentz, Martin Marietta, Nippon Electric Company, Sperry, Honeywell, Northrop, Bendix, and Singer. The introduction of fiber-optic gyros into the field has been relatively rapid with the delivery by McDonnell Douglas of production prototypes in 1985, to support an oil field borehole survey tool.

However, significant engineering issues remain to be solved before fiber-optic gyros with performance characteristics similar to "inertial navigation" grade ring laser gyros are available.

28 D009A

ABSTRACT

Distributed-feedback AlGaAs lasers of 720-780 nm emission wavelength with GaAs lattice matched InGaAsP waveguide layers are fabricated. The LOC structure is grown - on GaAs substrate by liquid phase epitaxy, and the laser diode fabrication is the same as the V-channeled substrate inner stripe lasers. They operate in a single-longitudinal-mode during temperature range of 40 °C. The threshold current as low as 145 mA for 720 nm and 120 mA for 780 nm are obtained under cw operation at room temperature.
Shortwave DFB lasers are desirable in the field of sensing and information processing with optics such as fiber optic gyroscope, laser beam printer, or an inetgration-optic disc pickup.

84 D035A

85 D037A

At the InterOpto show in Tokyo July 1989 Hitachi displayed a fiberoptic gyroscope targeted at the automotive-navigation market. The gyroscope operates with a 1-mW 830-nm diode laser and has a minimal signal rotation rate of +-0.01/s.

94 D040B

SEE PAGE# D040A FOR DETAILS

96 D042A

We have developed and improved Optical Heterodyne Fiber Gyro. The reference path has been introduced in the optical system, and the signal processing scheme has been adopted. We have successfully reduced the zero-point drift in the experimental setup.

97 D043A

Conclusion

We have shown theoretically and experimentally that the reflections in the light path outside the fiber ring results in a serious effects on the FOPRG performance. The phase modulation technique was found to be useful to reduce the effect of such reflections. It was pointed out that the optical phase modulator should be located outside the fiber. Furthermore, an external-cavity laser diode was first used in the FOPRG. The detection sensitivity as low as 3X10^5rad/sec (2Hz) was achieved with an integration time of 30 sec..

100 D044C

SEE PAGE# D044B FOR DETAILS

103 D047A

MITSUBISHI PRECISION DEVELOPS FIBER OPTIC GYRO

Mitsubishi Precision Co., Ltd, has developed a new fiber optic gyro which boasts the highest accuracy in the world. The new gyro will be installed for a flight test in the M rocket which the Institute of Space and Astronautical Science (ISAS) will launch next February.

If the test should be successful, ISAS plans to use the fiber optic gyro in the M5 solid rocket scheduled for launch in 1994. As a result, the company is expected to offer light-weight, low-cost and highly durable fiber optic gyro for practical use for the first time in the world in the early 1990s.

With regard to gyros used for guidance control of aircraft and rockets, ring laser gyros have the highest accuracy at present. However, the ring laser gyros are costly and weak against gravitational acceleration.

99 D044B

JAE is developing fiber optic gyros. The objective is to develop three grades of FOGs. The first is a moderate device with an accuracy of 100 deg-1000deg/hr. The second is a tactical grade with an accuracy of 0.1-10 deg/hr. It is currently in the brass-board development phase. The third, inertial grade FOG will have an accuracy better than 0.001 deg/hr.

The overall development program is aimed at the production of a rigid, small, light weight, highly stable, low cost optical circuit with a light source module, coupler, and integrated

optics. The signal processing circuit will have wide dynamic range and have effective error compensation.

The major problems to be overcome include the stability of components and the development of the signal processing circuit. Also, JAE is currently using 0.83 um superluminescent diodes (SLDs) as their light source which are purchased from the U.S..

1 D0000

ATTITUDE CONTROL SYSTEMS FOR HEAVY SPACECRAFT

Attitude control system (ACS) requirements for a given mission are defined directly by the payload and indirectly by other subsystems that are in turn defined by the payload. In remote sensing missions, usually, the main body of the spacecraft is maneuvered into the desired attitude while multiple payloads and or antennas may be pointed independently, while in an orbit ranging from low earth to above geosynchronous (35,800 km) altitude. In contrast, communications spacecraft are usually maintained in a nominal nadir (earth pointing) attitude, and often in a geosynchronous, or Molniya orbit (an eccentric egg-shaped orbit used to maximize the spacecraft's time over a specific point on earth).

Controlling the attitude of a spacecraft or of any separately pointed appendage is an example of the classic control problem. An input command gives the desired state of the system. When transmitted to the actuator this input changes the state of the system. The response of the system is measured by a sensor which generates a feedback signal to the summing point. Here the feedback signal is compared to the command and the difference, if any, forms an error signal, which is applied to the control circuits to produce a correcting input to the actuator. When the spacecraft is rigid and has solid components, the control circuits can be straightforward, but most large spacecraft are flexible with low frequency bending modes that can be excited by the control system, resulting in unstable (oscillating) conditions.

Subsystems other than the payload such as solar arrays and telemetry antennas will also have pointing requirements that must be satisfied. Attitude control may also be required when the orbit or trajectory of the spacecraft must be changed, and to correct for cyclic and secular disturbance torques such as those caused by aerodynamic pressures, light (solar) pressure, magnetic effects, gravity gradient and internal torques from moving parts within the spacecraft. While the spacecraft attitude is controlled by the devices described below, the attitude of its appendages will be controlled by a variety of drive mechanisms powered by DC torque motors and stepper motors.

A number of techniques are used to stabilize spacecraft and the choice is always driven by mission requirements.

Spinning Spacecraft - (at 2 to 5 rpm) is the least expensive means of attitude control and only requires the occasional firing of spin thrusters and the use of a precision thruster to correct for disturbance torques or to reorient the vehicle.

Dual-Spin Spacecraft - is a spinning spacecraft in which the payload (antenna or sensor) is continuously pointed in one direction (usually at earth) by spinning that portion of the space craft in the opposite direction at the same speed. It uses a motor and bearing assembly to support and despin the payload.

Zero Momentum Spacecraft - is a spinning spacecraft with a momentum wheel mounted on its spin axis and rotating in the opposite direction at an appropriate speed to cancel out the angular momentum and permit reorientation with very small thrusters.

All-Gas Spacecraft - have no spinning components and generate the momentum required to alter their attitude by expelling gas through the thrusters (one pair on each of 3 axes).

Momentum Biased Spacecraft - are stabilized in three axes. They use an internal momentum wheel which keeps one axis stabilized in two coordinates in inertial space and payloads are mounted so that attitude changes of this axis are not needed. Rotation about the spin axis is accomplished by changes in wheel speed.

Reaction Wheel Spacecraft - are stabilized by reaction wheels mounted on all the axes and reorientation about any axis is accomplished by changing the speed of that wheel or changing its direction of rotation.

Control Moment Gyro Spacecraft - use either 3 single axis CMGs or 2 double axis CMGs. All wheels are run at continuous speed but the spacecraft is reoriented about the CMG by rotating their gimbal axes. Stabilization Components (Actuators)

The actuators used to manipulate the spacecraft into the desired attitude include thrusters, momentum wheel, reaction wheel, or the control moment gyro.

Attitude Sensors

One or more of a variety of sensors may be employed to measure the actual attitude of the spacecraft with respect to the earth or the universe. The two major classes of sensors are "inertial" (which can only measure changes in attitude) and "absolute" or external sensors (which can be pointed at a target of known position). Inertial sensors are primarily gyros of either the floated, dry-tuned, ring-laser, or fiber-optic design, while point sensors detect RF sources, stars, the sun, earth or a surface feature.

2 D0000

SEE DESCRIPTION UNDER SHEET A

24 D005C

MAIN ITEMS WHICH THE COMPANY PRODUCES OR SELL FOR THE SPACE BUSINESS:

* ROCKET
* ROCKET ENGINES
* ATTITUDE CONTROL DEVICES
* SATELLITE EQUIPMENT

27 D008A

This paper deals with the problem of controlling the vibrations of large space structures by use of a newly conceived torque actuation device, i.e., a tendon control system. It consists of a pair of tension cables transmitting a control torque to the structure at the moment arm position. The purpose of this study is twofold: first, to establish the analytical framework for low-authority control synthesis; second, to validate the

proposed concept through a hardware experiment. A nonlinear optimization approach is proposed for the design of control gains and the moment arm placement. This approach is useful when the total number of control devices is smaller than the number of critical vibration modes, an exact pole placement is not possible. A hardware experiment has been done successfully, which shows the fundamental feasibility of the active tendon control for a highly flexible beam. However, for its practical application, further studies are needed, especially on the interactions between the dynamics of the tension cables and the flexible structure.
The table below presents the theoretically and experimentally determined natural frequencies of the lowest eight modes. The theoretical natural frequencies without gravity are listed in the first column to show that the gravity effect is remarkable, especially at lower frequencies.

NATURAL FREQUENCIES FOR BEAM (Hz)

	Euler-Bernoulli Theory		Timoshenko	
Modes	Without g	With g	With g	Experiment
1	0.14	0.42	0.42	0.42
2	0.88	1.28	1.28	1.28
3	2.42	2.90	2.90	2.92
4	4.74	5.26	5.26	5.35
5	7.83	8.39	8.39	8.55
6	11.70	12.29	12.28	12.45
7	16.34	16.93	16.93	17.33
8.	21.76	22.35	22.36	22.85

32 D013A

EXPERIMENTAL GEODETIC PAYLOAD

Experimental Geodetic Payload (EGP) will be placed in orbit by NASDA's first experimental launch vehicle of H-I rockets in the winter of Japanese fiscal year 1985. Using EGP, the map of Japan and the location of isolated islands will be investigated accurately by the Geographical Survey Institute of the Ministry of Construction and the Hydrographic Dept. of the Maritime Safety Agency in the Ministry of Transport.

MAJOR SPECIFICATIONS

ORBIT	ALTITUDE APPROX 1500KM
	INCLINATION APPROX. 50 DEG.
WEIGHT	APPROX. 700KG.
CONFIGURATION	POLYHEDRON INSCRIBED IN A SPHERE WITH
DIAMETER	2.15 METERS
MIRRORS	315 PIECES
LASER REFLECTORS	120 SETS
ATTITUDE CONTROL	SPIN STABILIZATION

55 D027C

The National Space Development Agency is developing an attitude control system for the ETS-6 (Engineering Test Satellite) to be launched in 1992. Using an attitude control signal processor and a solar sensor by Toshiba, a NEC earth sensor, and a Mitsubishi precision inertial guidance device, the system was tested in early 1988 on a satellite motion simulator at the Tsukuba Space Center. The devices tested are breadboard models but are reported to be equal in performance to foreign-manufactured

67 D031A equipment now aboard ETS satellites.

Attitude determination

The ways to stabilize the satellite attitude are generally categorized into two groups: spin stabilization and three axis stabilization. While three axis stabilization is suitable for a satellite which has a complex body and needs precise attitude control, spin stabilization is frequently used because it is simple. Spin stabilization is based on the conservation of angular momentum, which explains the stability of a rotating top. Most satellites launched in Japan, such as communications satellites (CS series), broadcast satellites (BS series), and geostationary meteorological satellites (GMS series), are spin-stabilized in the transfer orbit. These satellites change their attitude to meet night conditions. During this phase, the direction of the spin axis is continuously determined by using telemetry data transmitting from the satellite to ground tracking stations.

Determining the attitude generally requires measuring of two angles, that is, the angle between the spin axis and the sun, Θs, and the angle between the spin axis and the earth, Θe. These angles are calculated from data obtained by onboard earth and sun radiation sensors. Each angle generates a cone centered on the axis toward the sun or the Earth. Since the spin axis simultaneously satisfies both Θs, and Θe, it must be on the intersection of the cones. Although there are two intersecting lines for each pair of cones, only one will remain unchanged when measurements are retaken later.

As previously mentioned, the direction of the spin axis is uniquely determined by data obtained from sensors at different times. However, this procedure does not give the precise attitude of the satellite, because sensor data is always biased and noisy. In practice, sensor data is collected several times, and the direction of the spin axis is determined using the least squares method. In this method, not only the attitude but the sensor biases are estimated, and this bias estimation leads to an accurate determination of the attitude. The least squares method and the sensor data processing are incorporated in the attitude determination program, used during satellite tracking.

83 D035A

Very sensitive pyroelectric IR detectors for satellite navigation were developed by researchers at the Matsushita Research Center and the NASDA office in Ibarki. Two detectors, one made of lead titanate ceramic and the other a sputtered expitaxial film of calcium-modified lead titanate, were tested for use in the Engineering Test Satellite VI to be launched in 1992. The random error of attitude measurement was 0.03 deg. for the first detector and 0.012 deg for the latter.

87 D039A

ON OCTOBER 6, 1989, NOAA SCIOFF MET WITH OFFICIALS OF JAPAN'S NATIONAL SPACE DEVELOPMENT AGENCY (NASDA) TO LEARN THE STATUS OF THE JAPANESE - GEOSTATIONARY METEOROLOCICAL SATELLITE (GMS) PROGRAM. SINCE 1977 A TOTAL OF THREE GMS SATELLITES, IN SEQUENCE, HAVE PROVIDED METEOROLOGICAL AND ENVIRONMENTAL DATA SERVICES TO USERS IN JAPAN AND OTHER COUNTRIES THROUGHOUT ASIA. GMS AND GMS-2 HAVE BEEN RETIRED AND DEORBITED. GMS-3, CURRENTLY OPERATIONAL

BUT EXPERIENCING SOME TECHNICAL PROBLEMS, WILL SOON BE REPLACED BY THE RECENTLY LAUNCHED AND TECHNICALLY IMPROVED GMS-4. DESIGN AND DEVELOPMENT OF THE NEXT SATELLITE IN THE SERIES, GMS-5, IS UNDERWAY, AND LAUNCH IS SCHEDULED FOR 1993-1994. AS WITH ALL PREVIOUS GMS SPACECRAFT, GMS-5 WILL BE SPIN-STABILIZED. GMS-5 ALSO WILL HAVE ENHANCED IMAGING CAPABILITIES AND WILL CONDUCT A NEW SEARCH AND RESCUE (SAR) BEACON RELAY EXPERIMENT. A COMBINED METEOROLOGICAL/COMMUNICATIONS/SAR MISSION IS BEING CONTEMPLATED FOR GMS-6. THE SIZE AND WEIGHT OF SUCH A MULTIMISSION PAYLOAD WOULD REQUIRE A SPACECRAFT BUS DIFFERENT FROM THE ONE CURRENTLY IN USE , POSSIBLY REQUIRING A SWITCH TO A THREE-AXIS STABILIZED SPACECRAFT. A PREPHASE-A GMS-6 FEASIBILITY STUDY IS TO BEGIN THIS YEAR, AND LAUNCH IS TENTATIVELY SCHEDULED.

88 D039B

LATE NOVEMBER-EARLY DECEMBER OF THIS YEAR GMS-3 WILL RELINQUISH ITS POSITION TO THE APPROACHING GMS-4 AND BEGIN ITS MOVE WEST TO A STANDBY STATION AT 120 DEGREES EAST LONG. GMS-4 WILL ASSUME THE OPERATIONAL 140 DEGREES EAST LONG POSITION BY EARLY DECEMBER. GMS-3 OPERATIONS AT 120 DEGREES EAST LONG WILL BE ABLE TO MONITOR WEATHER FRONTS MOVING EAST OVER THE ASIAN MAINLAND AND PROVIDE BETTER COVERAGE OF DEVELOPING MONSOON CONDITIONS. DATA WILL BE DISSEMINATED THROUGH ESTABLISHED WORLD METEOROLOGICAL ORGANIZATION (WMO) NETWORKS AND UTILIZED BY NATIONS OF THE REGION.

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GMS-4 CHECKOUT. GMS-4 CURRENTLY IS STATIONED AT 160 DEGREES EAST LONG IN ITS "GEOSTATIONARY ORBIT SUBPHASE" OF POST-LAUNCH CHECKOUT. ATTITUDE CONTROL AND COMMUNICATIONS SYSTEMS ARE NOW BEING TESTED, AND IMAGING SYSTEM TESTS OF ONE MONTH'S DURATION ARE SCHEDULED TO BEGIN OCTOBER 16. PLANS ARE BEING MADE FOR ITS FINAL WESTWARD MANEUVER TO 140 DEGREES EAST LONG, AND OPERATIONAL COVERAGE IS EXPECTED TO BEGIN ALMOST IMMEDIATELY UPON ARRIVAL IN EARLY DECEMBER. GMS-4 WILL CLOSE TO WITHIN FOUR DEGREES OF GMS-3 BEFORE NASDA GIVES THE COMMAND TO INITIATE THE MOVE OF GMS-3 TO ITS STANDBY STATION.

90 D039D

PREPARATIONS FOR GMS-5. DESIGN AND DEVELOPMENT OF THE GMS-5 SPACECRAFT IS UNDERWAY. LAUNCH ON A NASDA H-II ROCKET IS SCHEDULED FOR 1993- 1994. AS WITH PREVIOUS GMS SATELLITES, GMS-5 WILL BE SPIN STABILIZED. QUESTIONED ABOUT CRITERIA FOR THIS CHOICE, NASDA REITERATED THAT SPIN STABILIZED TECHNOLOGY WAS CHOSEN AGAIN LAST YEAR BECAUSE IT IS RELIABLE, AND BECAUSE A LIMITED BUDGET PRECLUDED THE MAJOR CHANGES IN GROUND SEGMENT HARDWARE AND SOFTWARE THAT WOULD BE NECESSARY FOR A SWITCH TO A THREE-AXIS STABILIZED SPACECRAFT.

91 D039E

PLANNING FOR GMS-6 . JMA, THE MARITIME SAFETY AGENCY, AND THE CIVIL AVIATION BUREAU--ALL WITHIN THE MINISTRY OF TRANSPORT--ARE CONSIDERING A COMBINED METEOROLOGICAL/COMMUNICATIONS/SEARCH AND RESCUE MISSION FOR THE NEXT-GENERATION GMS-6 SPACECRAFT. THE POTENTIAL COMMUNICATIONS/SEARCH AND RESCUE COMPONENT WOULD SERVE AN ENVISIONED NATIONAL AVIATION, MARITIME AND LAND TRANSPORT NAVIGATION/TRAFFIC CONTROL/TELECOMMUNICATIONS SYSTEM. NASDA STATED THAT SUCH A COMBINED MISSION WOULD REQUIRE A LARGER "MULTIMISSION" SPACECRAFT, AND THAT THE THREE-AXIS STABILIZED ETS-6 SATELLITE IS SEEN AS A POTENTIAL BUS. THEY WERE QUICK TO MENTION THAT THIS HAS YET TO BE DECIDED, AND THAT A "TRADE OFF STUDY" COULD BE DONE IN WHICH SPIN-STABILIZED TECHNOLOGY WOULD BE CONSIDERED AS ANOTHER OPTION. NASDA ALSO SAID THAT IF A THREE-AXIS STABILIZED BUS WERE CHOSEN, IT WOULD REQUIRE A U.S. "COES-NEXT TYPE IMAGER" (AS THERE CURRENTLY IS NO THREE-AXIS COMPATIBLE VISSR IMAGER). THE FUTURE GMS-6 IS TENTATIVELY SCHEDULED FOR LAUNCH IN 1998. NASDA SAID A "PRE-PHASE A" STUDY WOULD BEGIN THIS YEAR, WITH A PHASE A STUDY SOON TO FOLLOW.

98 D044A

JAE major research thrusts are in inertial navigation and guidance systems; inertial sensor technologies such as gyros, accelerometers, and ring laser gyros; automatic flight control systems including auot stabilization, yaw dampers, and fly-by-wire-control configured vehicles; and microwave technology for radar altimeters.

Inertial navigation systems include several conventional gyros in routine production for aircraft, missle, torpedo and helicopter applications. JAE also produces one axis accelerometers. JAE is developing several ring laser gyros of their own. One system will be qualified for use in the NASDA H-2 rocket.

JOINT VENTURES WITH U.S. COMPANIES

GENERAL ELECTRIC	F4E & F15J FLIGHT CONTROL SYSTEM
HAMILTON STANDARD	FLIGHT STABILIZATION SYSTEMS FOR ASW HELICOPTERS
HONEYWELL	F-104 FLIGHT CONTROL SYSTEM RADAR ALTIMETER
TELEDYNE AVIONICS	NO PROJECT SPECIFIED
GOULD	NO PROJECT SPECIFIED

101 D045A

Japanese scientists have reported that small gyroscopes lose weight when spun under certain conditions, apparently in defiance of gravity. If proved correct, the finding would mark a stunning scientific advance, but experts said they doubted that it would survive intense scrutiny.

A systematic way to negate gravitation, the attraction between all masses and particles of matter in the universe, has eluded scientists since the principles of the force were first elucidated by Issac Newton in the 17th century.

The anti-gravity work is reported in the Dec. 18 issue of Physical Review Letters, which is regarded by experts as one of the world's leading journals of physics and allied fields. Its articles are rigorously reviewed by other scientists before being accepted for

publication, and it rejects far more than it accepts.

Experts who have seen the report said it seemed to be based on sound research and appeared to have no obvious sources of experimental error, but they cautioned that other seemingly reliable reports have collapsed under close examination.

The work was performed by Hideo Hayasaka and Sakae Takeuchi of the engineering faculty at Tohoku University in Sendai, Japan. Unlike the exaggerated claims made for low-temperature, or cold, nuclear fusion this year, the current results are presented with scientific understatement. The authors do not claim to have defied gravity, but simply say their results cannot be explained by the usual theories.

More important, the experiment is outlined in rich detail, ensuring that other scientists can try to duplicate and assess it.

"It is an astounding claim," said Dr. Robert L. Park, a professor of physics at the University of Maryland who is director of the Washington office of the American Physical Society, which publishes Physical Review Letters. "It would be revolutionary if true. But it's almost certainly wrong. Almost all extraordinary claims are wrong."

Dr. Robert L. Forward, a consultant who helps the Air Force investigate advanced forms of propulsion, including claims of anti-gravity devices, said: "It's a careful experiment. But I doubt it's real, primarily because I've seen so many of these things fall apart."

If substantiated by further tests, the finding could have a profound influence on physics and the study of the universe and perhaps in the making of practical anti-gravity devices.

The experiment looked at weight changes in spinning mechanical gyroscopes whose rotors weighed 140 and 176 grams or 5 and 6.3 ounces. When the gyroscopes were spun clockwise, as viewed from above, the researchers found no change in their weight. But when spun counter clockwise, they appeared to lose weight.

The rate of decrease was small, ranging up to 11-thousandths of a gram when the gyroscopes turned at 13,000 revolutions per minute. But two effects were significant. First, the weight loss increased as speed did. Second, the pattern was stronger with the larger gyroscope, indicating that the results might be applied to still larger objects.

The Japanese scientists said the weight measurements were carried out 10 times at speeds between 3,000 and 13,000 revolutions per minute. Forward, noting that the observed reduction amounted to a weight loss of 20 to 60 parts per million, called it "a big effect."

In their paper, the Japanese scientists outlined an extensive search or possible sources of experimental error, including stray magnetic fields, vibrations and defects in the gyroscopes and measuring devices. For instance, they took the apparatus to a special room

that was free of magnetic fields, and they tried to damp out all possible vibrations.

They placed the gyroscopes right side up and upside down, to rule out simple gravitational effects. They also conducted the tests in a vacuum, to rule out the influence of air currents, and used two different systems for measuring the weight loss.

They reported no experimental errors. They also offered no explanation for the effect and no speculation on the possibility of creating anti-gravity engines for planes and spaceships. In their one concession to vivid language, they called the phenomenon "extraordinary."

Park of the University of Maryland said the finding, if proved true, would "almost certainly" be explained by general relativity. Albert Einstein's geometric theory of gravitation.

Forward, who aids the Air Force in its propulsion work, said the sheer volume of bogus anti-gravity claims threw doubt on the validity of the new finding. About a dozen extraordinary claims are made for rotating devices each year, he said, and in nearly all of them the effect turns out to be caused by stray vibrations.

Both Park and Forward said the next step is for independent researchers to see if the results of the Japanese scientists can be duplicated.

10 D0000

THRUSTER - GAS

A spacecraft can be stabalized about its 3 axes by three sets (opposed pairs) of small gas thrusters, but the propellants would be quickly depleted by the continual small corrections necessary to keep an earth-orbiting spacecraft pointed in the desired direction. Attitude control actuators that utilize a replaceable energy source, such as electrical power from solar arrays, are more desireable for long duration spacecraft missions.

14 D001A

REACTION CONTROL - CS-3 COMMUNICATION SATELLITE

Reaction control subsystem (RCS) provides thrust to change the attitude and velocity of the spacecraft. RCS subsystem controls the orientation of spacecraft before the AKM firing in the transfer orbit, and performs spacecraft attitude normalization to operational orientation, launch vehicle injection error correction, station acquisition, station keeping and attitude control throughout "the life of the spacecraft.

The RCS has four monopropellant thrusters (nominal 20 N thrust each) the fuel of which is supplied by three interconnected tanks with a combined capacity of 110.5 kg. Each thruster selected by ground command, is fired in 90 ms pulses. Two redundant radial thrusters, mounted on the edge of equipment platform, carry out east/west orbital maneuvers. Their thrust axes are perpendicular to the satellite spin axis and pass approximately through the satellite center of mass. Other redundant axial thrusters are located at the bottom of spacecraft, just inside the solar array. These thrusts are tilted by 6 deg. to the spin axis.

Velocity increments are provided by one radial thruster pulsed once per spacecraft revolution, about the spacecraft angular position to obtain the desired velocity Attitude changes accomplished using one axial thruster. Again, a pulse is fired once per revolution at the angular position until the desired precession angle is achieved.

RCS PERFORMANCE CHARACTERISTICS

PARAMETER	CHARACTERISTICS
PROPELLANT MONOPROPELLANT	HYDRAZINE LOW CARBON
PROPELLANT STORAGE TANKS VOLUME 167.070cm^3 NOMINAL)	THREE SPHERICAL TANKS
FEED SYSTEM PRESSURIZED	UNREGULATED INERT-GAS
PRESSURANT OPERATING PRESSURE RANGE	SPIN ORIENTED BLOW DOWN HELIUM GAS 24.6 kg/cm^2 a (350 PSI A) INITIAL: 7.0 kg/cm^2 a (100 PSI A) BLOWDOWN
PROPELLANT CAPACITY MAXIMUM	118.5 kg MAXIMUM AT
PROPELLANT TEMPERATURE	PRESSURE BLOWDOWN RATIO 5 DEG C TO 60 DEG C
MAXIMUM EXPECTING OPERATING PRESSURE	28.1 kg/cm^2 a (400 PSI A)
THRUSTER THRUST	20 N

20 D003D

SEE PAGE# D003A FOR DETAILS

22 D005A

NIPPON OIL AND FATS SPACE BUSINESS ITEMS INCLUDE:

* COMPOSITE PROPELLANTS
* ROCKET ASSEMBLY MOTOR

23 D005B

MAIN ITEMS WHICH THE COMPANY PRODUCES AND SELLS FOR SPACE BUSINESS:

* A50
* ANAHYDROUS HYDRAZINE
* HIGH-QUALITY HYDRZINE
* VARIOUS TYPES OF ANALYSIS EQUIPMENT

26 D007A

MUSE-A

The ISAS (Institute of Space and Astronautical Science) has started a new project, Muse-A, by the approval of the Space Activities Commission.

MUSES is an acronym for Space Engineering Spacecraft launched by the Mu rocket which is a three stage solid rocket developed by ISAS.

MUSES-A is dedicated to a mission of double lunar swingby which

is a mandatory technology to be mastered before Geotail, a joint US-Japan program for ISTP (International Solar Terrestrial Physics program). Besides the swingby, the MUSES-A spacecraft will carry a tiny satellite at attached to the top, and inject it into an orbit around the moon prior to the first lunar swingby.

Japanese planetary scientists regard the mission of MUSES-A not only as a verification of Technology for Geotail, but also as a precursor for future scientific lunar exploration. Recent study carried out in a planetary scientist group has brought a concept of a lunar probe carving penatrators and some remote sensing instruments.

29 D018A

41 D018B

SEE PAGE# D018A FOR DETAILS

46 D020C

RCS

Sufficient thrust to accomplish satellite maneuvers is provided by the Reaction Control Subsystem (RCS). These maneuvers include active nutation control during transfer orbit, correction of initial satellite orbit due to injection errors, performance of coarse and fine spin-axis precession maneuvers, connection of east-west and north-south orbit drift, control of satellite spin rate, and change of orbital station.

The subsystem is composed of three conisphere tanks with a maximum propellant load capability of 40.8kg hydrazine, six 4.45 Newton thrusters, one fill and drain valves, two filters, two latch valves, and associated manifolds. The six thrusters are configured into two groups consisting of two radial and one axial thrusters each, providing redundancy. Separate feedlines supply propellant from the common propellant manifold to each thruster group. Each feedline contains a filter to remove particle contamination and a latching valve to isolate the thruster group in case of excessive leakage or open failure of any thruster valve.

Thrust is provided by the catalytic decomposition of liquid monopropellant hydrazine.

RCS CHARACTERISTICS

Functions	Provides attitude and orbit control, spin-up and spin speed control, and station change velocity
Design	Hydrazine propellant, helium pressurant, blowdown unregulated feed, titanium

Number of Thrusters	2 axials; 4 radials, canted
Thrust Level	4.45 Newton
Propellant Load	34 kg nominal, 40.8 kg max.
Tank Pressure	2.55 MPa initial, 1.26 MPa final

75 D021A

49 D023A

1N Hydrazine Thruster

Propellant	Hydorazine
Thrust Range	0.95 - 0.32 N
Specific Impulse	210 - 180 S Lower Limit
Total Impulse	42,895 (NxS)
Mode of Operation	
Pulse	125,500
Steady State	52,712.
Current Status	Qualified 1985 (ETS-V RCS) Flight Proven 1982 (ETS-III) (MOS-1)

50 D023B

20N THRUSTER

Propellant	Hydorzine
Thrust Range	19.6 - 6.9 (N)
Specific Impulse	226 - 210 (S)
Total Impulse	236,734 (NxS)
Mode of Operation	
Pulse	16,000 (Pulses)
Steady State	17,350 (S)
Current Status	Qualified 1985 (CS-3 RCS)

52 D026A

DEVELOPMENT OF MPD THRUSTER FOR SPACE USE

A 1kw-class MPD (Magneto-Plasma-Dynamic) thruster has been developed for EPEX (Electric Propulsion Experiment) planned as onboard experiment of SFU. In FY87, a preliminary design and a development of BBM for thruster and propellant supply subsystem have been conducted. The results of the development are going to be reflected in the design of EM (Engineering Models)

FINAL TARGET OF THRUSTER CHARACTERISTICS

	RESULTS	TARGET
THRUST POWER RATIO (mW/kw)	46	50
SPECIFIC IMPULSE (SEC)	590	800
THERMAL EFFICIENCY (%)	70	80
ENDURANCE (SHOTS)	3,000,000	10,000,000
WEIGHT/1 THRUST	10	5

59 D028D

SEE PAGE# D028A FOR DETAILS

62 D029A

THE 14TH SCIENCE SATELLITE - SOLAR A

MISSION	OBSERVATION OF SOLAR FLARE, CORONA & SOLAR MAGNETIC FIELD
ORBIT	600 KM NEAR CIRCULAR INCLINATION ANGLE 30 DEG.
WEIGHT	420 KG

LAUNCH VEHICLE M-3S II-6

64 D030B

ENGINEERING TEST SATELLITE-VI (ETS-VI)

* VERIFICATION OF H-II LAUNCH VEHICLE PERFORMANCE

* ESTABLISHMENT OF BASIC TECHNOLOGY REQUIRED FOR THE BUS SYSTEMS OF A TWO-TON CLASS THREE AXIS STABILIZED GEOSTATIONARY SATELLITE FOR USE IN TELECOMMUNICATIONS.

* LAUNCH DATE/VEHICLE: 1993/H-II

* EXPERIMENTERS: NASDA, MINISTRY OF POST & TELECOMMUNICATIONS, RADIO RESEARCH LABORATORIES, NIPPON

* PRIME CONTRACTOR: TO BE DETERMINED

89 D039C

LATE NOVEMBER-EARLY DECEMBER OF THIS YEAR GMS-3 WILL RELINQUISH ITS POSITION TO THE APPROACHING GMS-4 AND BEGIN ITS MOVE WEST TO A STANDBY STATION AT 120 DEGREES EAST LONG. GMS-4 WILL ASSUME THE OPERATIONAL 140 DEGREES EAST LONG POSITION BY EARLY DECEMBER. GMS-3 OPERATIONS AT 120 DEGREES EAST LONG WILL BE ABLE TO MONITOR WEATHER FRONTS MOVING EAST OVER THE ASIAN MAINLAND AND PROVIDE BETTER COVERAGE OF DEVELOPING MONSOON CONDITIONS. DATA WILL BE DISSEMINATED THROUGH ESTABLISHED WORLD METEOROLOGICAL ORGANIZATION (WMO) NETWORKS AND UTILIZED BY NATIONS OF THE REGION.

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A) THE INCLUSION OF DOMESTICALLY DEVELOPED USB TRANSMITTER-RECEIVERS AND HIGH FREQUENCY SECTIONS OF THE S-BAND TRANSMITTERS AND DRIVER AMPLIFIERS,

B) THE SUBSTITUTION OF LED ENCODERS FOR CONVENTIONAL ENCODER BULBS IN THE VISSR IMAGER,

C) AN IMPROVED INFRARED CALIBRATION CAPABILITY.

D) THE COATING OF THE SPACECRAFT'S OUTER SURFACE TO PREVENT ELECTROSTATIC DISCHARGE, AND

E) THE ADDITION OF EXTRA STATIONKEEPING HYDRAZINE PROPELLANT FUEL TO SUPPORT THE SATELLITE'S FIVE YEAR DESIGN LIFE.

NASDA STATED THAT VISSR IMAGER LUBRICANT PROBLEMS EXPERIENCED BY GMS-3 ARE EXPECTED TO BE ALLEVIATED BY THE INCREASE BY 1.5 TIMES OF THE SCANNING MIRROR/DRIVE MOTOR POWER.

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95 D041A

A quasisteady multimegawatt magnetoplasmadynamic (MPD) thruster with applied magnetic fields has been investigated to achieve the high-thruster performance at specific impulse levels between 1000 and 2000s, which is demanded for space missions near the Earth. The applied field coils are connected in series with a power source (pulse forming network). Field application causes lower discharge voltages and greater thrusts than those for no applied field in the following specific conditions:

1) the axial applied field intensity is equal to the azimuthal self field intensity only in the main region for current conduction, when the Joule heating is enhanced, and outside the region is very small;

2) the magnetic field lines are parallel throughout the inside surface of the anode. Furthermore, from the viewpoint of cathode life, it is worthy to note that the cathode erosion rate with the applied field is reduced to about half that with only the self-field.

5 D0000

STAR SENSOR - CHARGE COUPLED DEVICE (CCD)

Imaging CCD (ICCD) sensors will be able to obtain higher accuracy than conventional star trackers. A CCD is useful as a sensor because silicon is photosensitive and incident photons cause the creation of electron-hole pairs, and the electrons (or holes) can be collected in the potential wells of the CCD and processed to yield image data.

An ICCD may consist of a single CCD divided into picture elements (pixels), each corresponding to a potential well from which the electrons generated by incident photons are transferred out, measured, and transferred as a voltage to the image processing electronics.

Using 1982 technology, pixel size was limited to not less than .001 to .006 inch on a side, and the number of pixels to about 500x500. With these dimensions, locating a star to a given pixel would not provide sufficient accuracy for attitude control purposes. It is necessary to locate the star image to an accuracy of about 1/30th of a pixel. The technique used was to defocus (aberrate) the star image so that covers several pixels and then measure the electron charge in each of the pixels to compute the centroid or median of the image. There must be sufficient integration time to allow enough photons to strike the CCD so that a measurable quantity of electrons are generated in the potential well, which are far above the thermally generated dark current of electrons which occurs without any incident photons. The point spread function (PSF) of any star sensor represents the two dimensional shape and intensity of the image over the array area and is determined by the design of the optical system. The PSF must be considered in the algorithm that is used to compute the center of the image.

48 D022A

The star-tracker provides precise attitude reference for the control of various types of sophisticated spacecraft systems. The star-tracker acquires and tracks a fixed star(s) on the CCD, and produces data of the accurate position and magnitude of the star for the spacecraft attitude reference. High accuracy of the star-tracker is realized using a 2-dimensional CCD

(uPD3511D) detector developed by NEC. A pair of microprocessor-controlled CCD star-trackers are employed on Japan's latest X-ray astronomy satellite, ASTRO-C, to be launched in February, 1987

SPECIFICATIONS

FIELD OF VIEW	8DEG x 6DEG
DETECTOR PIXEL #	384H x 490V
FOCAL LENGTH	70mm
LENS DIAMETER	70mm
EXPOSURE TIME	250 msec - 1 sec
OPERATING MODE	MAPPER, TRACKER, STANDBY
POWER CONSUMPTION	6W MAX, 9WIN CASE OF COOLING
DEVICE	
SIZE	OPTICS 12x12x15cm ELECTRONICS 15x19x21cm
WEIGHT	OPTICS 4.5 kg ELECTRONICS 3kg

63 D030A

THE 14TH SCIENCE SATELLITE - SOLAR A

MISSION	OBSERVATION OF SOLAR FLARE, CORONA & SOLAR MAGNETIC FIELD
ORBIT	600 KM NEAR CIRCULAR INCLINATION ANGLE 30 DEG.
WEIGHT	420 KG
LAUNCH DATE	AUG 81
LAUNCH VEHICLE	M-3S II-6

69 D033A

CCD STAR SENSOR FOR TF-I NAL PAYLOAD (JINDAI)
TF-I HI ROCKET TEST FREIGHT

FLOWN IN FY 1986
SENSING TECHNIQUE - AREA CCD MAPPER
OPTICS - f=55mm F/1.2
FOV - 9.2degX6.8deg
SENSITIVITY - 6 VISUAL MAGNITUDE
DETECTOR - TCD203C (TOSHIBA) 400 (H)X500(V)
INTEGRATION TIME - 528msec
ACCURACY - 0.05 DEG
POWER - 11W
WEIGHT - 3.7 kg

6 D0000

STAR SENSOR - IMAGE DISSECTOR

The reliable detection of stars in full daylight is a signal-to-noise ratio problem. The magnitude of the signal depends upon the magnitude and type of star being observed, attenuation of starlight by earth's atmosphere, atmospheric turbulence, characteristics of optical system, the light detector employed, and the scanning technique employed. Performance of the star sensor is limited by shot noise developed at the light detector due to the light flux reaching it from the sky.

While newer star sensor utilize CCDs as the detector element, the conventional star sensor used on spacecraft has employed an image dissector tube as the detector element.

35 D016A

ASTRO-B SCIENTIFIC SATELLITE 8 "TENMA"

A scientific satellite (ASTRO-B) was launched on February 20, 1983 from Kagoshima Space Center by the M3S-3 launch vehicle. It was placed into a near circular orbit of 490 km perigee and 570 km apogee. It circles the earth every 96 minutes with an inclination of 32 degrees to the equator.

The ASTRO-B was developed by the Institute of Space and Astronautical (ISAS), Ministry of Education to observe the Spectra of galactic and extra-galactic X-ray sources. ISAS appropriately named their astronomical exploration satellite ASTRO-B the "TENMA", which is Japanese for the constellation Pagasus.

NEC supplied the major subsystems, most of the common bus equipment including satellite structure and solar cell paddles, NEC was responsible for the overall system design and system integration.

The TENMA weighing 220kg is spin stabilized and employs a geomagnetic attitude control. The main body of the satellite is an octagonal cylinder of 116.7 cm in diameter, 89.5 cm in height and 110.4 in width across opposite sides. A total of 3448 silicon solar cells are mounted on 4 deployable solar cell paddles that together generate about 180 watts of electrical power.

36 D016B

SEE PAGE# D016A FOR DETAILS

40 D018A

Japan's first interplanetary spacecraft "MS-T5" was launched on January 8, 1985 from Kagoshima Space Center by a M-3S II- launch vehicle. (International code number 1985-001A)ISAS (Institute of Space and Astronautical Science) named this spacecraft "SAKIGAKE" meaning pioneer in Japanese. "SAKIGAKE" was placed into heliocentric orbit beyond the gravity of the earth. It will orbit the sun one and a halftimes, and encounter Halley's comet in March 1986 at a distance of 7,000,000 km. "SAKIGAKE" was developed by ISAS to test spacecraft technology in deep space. NEC was responsible for the overall system design and system integration as well as the supply of the major subsystems and most of the common bus equipment.

MISSION

* Confirmation of performances of the M-3S II launch vehicle, and injection of spacecraft into interplanetary orbit
* Engineering experiments on interplanetary spacecraft
* Deep space communication
* Attitude determination and control
* Active thermal control
* Observation of interplanetary environment
* Solarwind ions
* Plasmawaves
* Magnetic fields

"SAKIGAKE" Up Close

The cylindrical body of "SAKIGAKE" is 1.4 m in diameter and 1.7 m in height including parabolic high gain antenna with despun mechanism. Solar cells are mounted around the body and generate approximately 80W of electrical power. For use in observation, one 2 m boom and two 5 m antennas extend from the body. The body spins to stabilize the spacecraft's attitude. Spin rate, spin axis orientation and orbit are controlled by six thrusters.

54 D027B

SEE PAGE# D027C FOR DETAILS

70 D033B

STAR SENSOR FOR ENGINEERING TEST SATELLITE MS-T4
(TANSEI-4)

FLOWN IN FY 1979
SENSING TECHNIQUE - N-SHAPED SLIT MAPPER
DETECTOR - PHOTOMULTIPLIER TUBE RCS C31016FL
ACCURACY 1 ARC MINUTE

71 D033C

STAR SENSOR - ASTRONOMICAL SATELLITE ASTRO-B - (TENMA)

FLOWN - FY1982
SENSING TECHNIQUE - N-SHADED SLIT MAPPER
SPIN RATE - 0.05 - 5RPM
SENSITIVITY - 4 VISUAL MAGNITUDE
FOV - 10degX10deg
DETECTOR - pmt rca C31016FL
ACCURACY - 1 ARCMIN
POWER - 0.74W
WEIGHT - 6.4 kg

82 D034A

IMAGE DISSECECTOR

The image dissector has a photoemissive surface (photocathode) and features random-access scanning and no lag. Unlike vidicons, image dissectors do not store an electric charge during the interval between scans, so they have a low apparent signal-to-noise ratio and are unsuitable for viewing on a TV monitor. They are used in special instrumentation applications.

Applications

- Random-access cameras
- High-speed tracking and measurement
- Vibration and displacement measurement
- Star tracking
- Two-dimensional photon counting
- Measurement of transmission characteristic of optical fibers

9 D0000

EARTH SENSOR

Earth sensors operate by scanning a beam across the earth disc to detect the horizon (or limb) at opposite sides, and then the center of the earth is calculated as half the distance between the two horizons. Some sensors also operate by scanning across a portion of the limb and computing the center of the arc. The scanning mechanism including the motor drive is a major contributor to the size a weight (7 to 11 lbs) of the unit. The accuracy of the sensors is also limited by the quantization noise of the encoder used to read out the instantaneous angle of the mirror that scans the beam.

Recent designs involve a resonant scan mechanism utilizing a flexure pivot on which the mirror is mounted, which oscillates at its natural frequency (similar to a pendulum), requiring very little power. They also employ a mathematical interpolation

scheme to increase the resolution of the optical encoder disk, far beyond its physical limitations. Optical encoders operating at near zero rates present problems that are continually being addressed by new research.

15 D0C2A

ATTITUDE CONTROL: CS-3 COMMUNICATION SATELLITE

The attitude and antenna control subsystem (AACS) provides azimuth pointing control for the communications antenna and information necessary to control satellite attitude. The subsystem consists of earth and sunsensor assemblies, nutation damper, despin motor assembly (DMA), orbital balancing mechanism (OBM), and redundant attitude and antenna control electronics (AACE) units.

The earth sensor assembly, consisting of two infrared optical sensors with axes above and below the plane normal to the satellite spin axis, generates earth horizon crossing reference pulses for antenna pointing. In addition, earth sensor signals are used for satellite attitude determination by providing earth chordwidth measurement, spin rate measurement during eclipse, and reaction control subsystem (RCS) thruster synchronization in a backup mode to the sun sensor.

The sun sensor assembly consists of two sensors. One sensor's field-of-view extends from +87deg to -30deg while the other extends from +30deg to -87deg providing redundant coverage in the +30deg to -30deg region. One sensor selected by ground command, produces a single pulse for each satellite revolution. Pulse length is a precise indication of sun elevation angle. The sun sensor assembly provides signals for system attitude determination (sun angle and spin rate measurements) and primary signals for RCS thruster synchronization.

Three OBMs, located on the lower equipment platform spaced 120deg apart, will be utilized to accurately adjust, on orbit, the spacecraft spin axis orientation to ensure coincidence between spin axis and the spacecraft principal axis in order to reduce spacecraft wobble and its associated antenna pointing errors.

The nutation damper is passive device consisting of a curved tube filled with neon gas and a free-rolling steel ball. Damping is primarily the result of gas viscosity created by a small (0.25mm) gap between the sphere and the tube's inner dimensions.

The drive motor assembly interfaces the spinning satellite and the despun antenna horn reflector. It consists of a shaft attached to the satellite, a housing attached to the antenna and two bearings. Electromechanical components are a brushless dc torque motor with redundant windings, a brushless commutating resolver with redundant windings, four magnetic rate and position sensors, and a single slipping to ground the housing to the shaft.

Attitude and antenna control electronics consist of two redundant units. Sun and earth sensor inputs, as well as magnetic pickups, are cross-strapped to the AACE units. Control and power circuits for the DMA resolver and motor windings are transferred from one AACE unit to the other through relay switches. Each unit contains electronic circuitry to process or control earth and sun sensor data, to provide antenna offset bias and antenna despin, and to encode attitude data.

AACS PERFORMANCE CHARACTERISTICS

PARAMETERS	CHARACTERISTICS
POINTING ACCURACY	<=0.2(3)(HALE CONE ANGLE)
TRACKING ACQUISITION TIME	<=15 MINUTES
SUN ANGLE MEASUREMENT	+-30 DEG SUN ANGLE +-0.47 DEG
EARTH WIDTH MEASUREMENT SINGLE READING (SYNCHRONOUS)	+-0.26 DEG
SPIN RATE MEASUREMENT	
PRIME MODE (SUN SENSOR)	+-0.07 RPM
ECLIPSE MODE (EARTH SENSOR)	+-0.15 RPM
NUTATION DAMPING	
TIME CONSTANT	<=1.5 MINUTES
THRESHOLD	+-0.05DEG
THRUSTER SNYCHRONIZATION PULSE	
PRIME MODE (SUN SENSOR)	+-0.15DEG
BACKUP MODE (EARTH SENSOR)	+-0.25DEG

19 D003C

SEE PAGE # D003A FOR DETAILS

74 D014A

45 D020B

SEE PAGENO D020A RECORD 46 MEMO FIELD FOR SYSTEM DESCRIPTION

76 D021C

51 D024A

Japan's first Earth observation satellite, MOS-1, is about to be launched, and the follow-on, ERS-1, is now under development. Moreover, the future earth observation program, including participation in the Polar Platform Program which is now under study within NOAA, NASA, ESA, is also studied in Japan.

The main mission objectives are as follows:

1) to establish the technologies of Earth observation from space by the Synthetic Aperture Radar and Optical Sensors.
2) to explore non-renewable resources and to monitor land use, agriculture, forestry, fishery, environmental protection, prevention of natural disasters, surveillance of coastal regions, ect.

53 D027A

SEE PAGE# D027C FOR DETAILS

57 D028B

SEE PAGE# D028A FOR DETAILS

61 D0000

SUN SENSOR - ANALOG

Sun sensors provide coarse and fine tracking for solar arrays, payloads or the spacecraft. They indicate the orientation of the sun with respect to a reference coordinate system by detecting

the intensity difference between radiation arriving from the solid angle determined by the sun's boundaries and that arriving from adjacent regions within the sensor's field of view.

In a simple one-axis analog sensor, the Sun's image, projected through an optical system, illuminates two closely space photo-sensitive elements. The difference between the current outputs developed across the two elements becomes the sensor output. As the illumination of both elements becomes nearly equal, the sensor output approaches zero. This is the null point of the sensor.

All sun sensors are comprised of a spectral filter, a spatial filter, a radiation sensitive element, and signal processing circuitry. The spectral filter is chosen to exclude spectral bands of radiation that might be received from an extraneous or misleading source. The spatial filter is a system of geometric features, within or external to the sensor, that enable interpretation of the direction vector between the system and the radiation source. The spatial filters in an analog system consist of imaging optics that projects the Sun's image onto the detectors, and a pair of detectors separated by a narrow slit. The angle of the Sun in the direction perpendicular to the slit can be varied by the attitude control system until the Sun's image is divided equally between the two adjacent sensors.

All components and materials of a sun sensor are subject to a harsh environment of radiation and thermal cycles. Analog sensors can employ a broad variety of detectors including: photomultiplier, silicon solar cell, silicon photo-transistor, photo-SCR, cadmium sulfide, and cadmium selenide.

Spacecraft often employ multiple sun sensors to circumvent the problems of shadowing that may be caused by appendages of the vehicle. While a single sun sensor provides angular data in one axis, two orthogonal sensors can provide a precise direction vector between the sun and the spacecraft.

16 D002B

SEE PAGE# D002A FOR DETAILS

18 D003B

SEE PAGE# D003A FOR DETAILS

72 D014B

38 D017A

SCIENTIFIC SATELLITE NO. 9 "OHZORA" (EXOS-C)

A scientific satellite (EXOS-3) was launched on February 14, 1984 from the Kagoshima Space Center by M-3S-4 launch vehicle. It was placed into an elliptical orbit of 353 km perigee and 865 km apogee. It circles the earth every 96 minutes with an inclination of 75 degrees to the equator.

The EXOS-C was developed by the Institute of Space and Astronautical Science (ISAS), Ministry of Education to observe the minor constitution in the middle atmosphere and interaction of energetic particles in the ionospheric plasma. ISAS appropriately named their exospheric exploration EXOS-C the OHZORA".

NEC supplied the major subsystems, most of the common bus equipment including satellite structure and solar cell paddles, NEC was responsible for the overall system design and system integration.

The OHZORA weighs 207 kg and its main body is an octagonal cylinder of 119 cm in diameter, 88 cm in height and 94 cm in width across the opposite sides. A total of 3,588 silicon solar cells are mounted on 4 deployable solar cell paddles that to get her generate about 160 watts of general power. The satellite has capabilities of on-board processing with redundant microprocessors, 3 axis attitude stabilization using a momentum wheel and rate integrated gyros. The function of the attitude control system is to orient one axis on the sun. Data obtained on-board are transmitted to the ground by UHF and S-band transmitter.

44 D020A

GMS-3 is a spin-stabilized geostationary meteorological satellite with mechanical despun antennas. GMSS-3 will be the GMS-2 protoflight spacecraft refurbished to provide more capability and modified to improve its reliability. Hence, the configuration and characteristics of the spacecraft are improved over those of the predecessor, GMSS-2 and most subsystems are night-proven.

The spacecraft consists of a despun earth-oriented antenna assembly and a spinning section rotating at 100 rpm. Despun S band and UHF antennas provide high gain for on-orbit communications with ground stations. Spinning sun and earth sensors supply reference signals in daylight and eclipse periods to control the despun assembly. A noncontacting RF rotary joint, mounted coaxially within a Despin Bearing Assembly (DBA), feeds RF signals between despun antennas and a spinning equipment shelf.

The spinning section includes VISSR and supporting subsystems. The forward assembly consists of VISSR, magnesium thrust tube, honeycomb equipment shelf, electronics, batteries, main wire harness, Reaction Control Subsystem (RCS) tanks and thrusters, solar panel, and thermal barriers. The aft assembly includes an Apogee Kick Motor (AKM), wire harness, AKM adapter, and separation hardware. The aft assembly is jettisoned after motor burnout.

The satellite mission life is 4--5 years due to the limited amount of on-board hydrazine fuel; however, the design life is 5 years. Redundancy of mission-critical functions is provided to ensure electronics lifetimes significantly in excess of 5 years. The solar panel power of 263 W includes an approximately 16W margin at the end of 5 years.

CONTROL SUBSYSTEM

The control subsystem consists of a Despin Bearing Assembly (DBA); redundant Despin Control Electronics (DCE's); redundant precision sun sensors, sun sensors, earth sensors, and accelerometers; a nutation damper; and two Dynamic Balance Mechanisms (DBM's).

DBA provides the mechanical interface between the spinning section, which give gyroscopic stability, and a despun antenna assembly, which is pointed at the earth. Pointing control is accomplished in DCE by computing spin-to-despun orientation information from DBA with spin-to-sun orientation information from the precision sun sensor. When the sun is in eclipse, the earth sensor is used in place of the precision sun sensor.

The sensor outputs are also used by DCE to generate timing signals required by VISSR and VDM for stepping the mirror, resetting the infrared channel, starting the scan line, etc. Similar reference signals are sent to the ground station for attitude determination and to time attitude correction maneuvers.

The accelerometer is used for Active Nutation Control (ANC). During transfer orbit, the satellite with AKM attached is unstable about its spin axis. Therefore, the spin axis tends to cone, or nutate, at a slowly increasing angle. This nutation angle is sensed by the accelerometer and ANC electronics in DCE. When the angle becomes approximately 0.3deg, the ANC electronics commands the thrusters to fire a short pulse which decreases the nutation angle.

In geostationary orbit after AKM and its adapter separation, the satellite is stable. Any nutation, which occurs, naturally decreases. However, a passive damper is included to ensure the rapid decrease of such nutation. The damper is a hoop partially filled with alcohol and is offset approximately 60 cm from the satellite center of gravity (cg). This offset position causes the damper fluid to effectively counteract nutation. Also damper position is so designed that the hoop plane-to-cg offset is zero during transfer orbit. This damper does not affect satellite stabilization during transfer.

Two DBM's are used to correct deviations in the dynamic balance of the satellite in order to prevent spin axis tilt.

ATTITUDE AND ORBIT CONTROL
SALIENT PERFORMANCE

Spin speed (on station)	100 +-1 rpm
Stationkeeping	1 deg N-S, 0.5deg E-W
Attitude maintenance	0.5 deg.
Attitude determination	+- 0.07 deg.
Attitude stability (N-S)	
Spin Axis	2.0p rad over 0.6 sec 24.6u rad over 25 min
Spin phase	2.81u rad over 0.6 sec 20.4p rad over 25 min
VISSR timing accuracy	0.15 deg Antenna E-W pointing accuracy 0.39 deg sun reference 0.56 deg earth refer

73 D021B
56 D028A

ENGINEERING TEST SATELLITE -V (ETS-V)

Engineering Test Satellite-V (ETS-V) is a three-axis stabilized geostationary satellite weighing about 550kg and will be launched using the three stage H-I rocket. The ETS-V has been developed aiming at the establishment of the basic technology of geostationary three-axis satellite employed the domestic new technologies. Also, mobile communications equipment is loaded on the ETS-V to test communications with ships and aircrafts.

MAJOR CHARACTERISTICS

SHAPE	BOX TYPE 1.4x1.67x1.74m
WEIGHT	1096kg AT LAUNCH 550kg LIFE
ATTITUDE CONTROL	3-AXIS STABILIZED
LIFE	>= 1.5 YEARS
RELIABILITY	>= 0.86
LAUNCH VECHICLE	H-I
LAUNCH DATE	SUMMER, 87
ORBIT	GEOSATIONARY 150 DEG E LONG CONTROL ACCURACY +-0.1 DEG OF BOTH LATITUDE & LONGITUDE

MAJOR BUS ITEMS

ATTITUDE CONTROL SYSTEM	CONTROLLED BIAS MOMENTUM
SENSORS	EARTH, SUN
THRUSTERS	20N

78 D033F

ANALOG SUN SENSOR FOR ENGINEERING TEST SATELLITE ETS-III

FLOWN - FY1982
FOR SOLAR PADDLE POINTING
SENSING TECHNIQUE - COSINE LAW
DETECTOR - SILICON SOLAR CELL
ACCURACY - 1.5 DEG

81 D033I

SUN SENSOR FOR TF-I NAL PAYLOAD (JINDAI)

FLOWN - FY 1986
SENSING TECHNIQUE - COSINE LAW
ACCURACY - 5 DEG
POWER 0.04W

60 D0000

SUN SENSOR - DIGITAL

Sun sensors provide coarse and fine tracking for solar arrays, payloads, or the spacecraft. They indicate the orientation of the Sun with respect to a reference coordinate system by detecting the intensity difference between radiation arriving from the solid angle determined by the Sun's boundaries and that arriving from adjacent regions within the sensor's field of view.

In a digital sun sensor the sun is imaged as a line across an array of separate elements. Each element produces a 1 or 0 binary bit in the multichannel output, depending on whether light reaches the element through the mask and whether the sensor 's output in each channel exceeds threshold values established in associated circuitry. The binary number assigned to the channel identifies the position of the light imaged on the array of elements. The plane established by the entrance slit (that limits the radiation to a line) and its identified position of instruction with the detector array, identify the position of the Sun (with respect to the spacecraft) in one axis.

All sun sensors are comprised of a spectral filter, a spatial filter, a radiation sensitive element, and signal processing circuitry. The spectral filter is chosen to eliminate spectral

bands of radiation that might be received from extraneous or misleading sources. The spatial filter is a system of geometrical features, within or external to the sensor, that enable interpretation of the direction vector between the system and the radiation source. The spatial filters in a simple digi tal sensor consists of an entrance slit (which limits the received radiation to a line), a mask that contains a pattern of cutouts, which correspond to an array of detectors beneath. It is the controlled passage of sunlight through the entrances lit and the intervening mask cutouts, and its activation of one or more strips in the detector array that identify the relative position of the Sun, in the plane (or axis) of this sensor.

All components and materials of a sun sensor are subject to a harsh environment of radiation and thermal cycles. Digital sensor can employ a broad variety of detectors including: photomultipiler, silicon solar cell, silicon photo-transistor, photo-SCR, cadmium sulfide, and cadmium selenide. Or they can be simple optical device which employs a linear CCD detector and a slit.

Spacecraft often employ multiple sun sensors to circumvent the problems of shadowing that may be caused by appendages of the vehicle. While a single sun sensor provides angular data in one axis, two orthogonal sensors can provide a precise direction vector between the Sun and the spacecraft.

77 D033E

DIGITAL SUN SENSOR FOR IONCSPHEA SOUNDING SATELLITE ISS

FLOWN - FY1977 & FY1979
SENSING TECHNIQUE - V-SHAPED SLIT
SPIN RATE - 6-30 RPM
ACCURACY - 1.5 DEG

80 D033H

SUN SENSOR FOR TF-I NAL PAYLOAD (JINDAI)

FLOWN - FY1986

SENSING TECHNIQUE - LINEAR CCD+NSLIT
FOV - 50degX50deg 2 AXIS
INTEGRATION TIME - 7.9msec
ACCURACY - 0.05DEG
POWER - 2.8W
WEIGHT - 2.0Kg2

79 D033G

CCD DIGITAL SUN SENSOR
FOR ASTRONOMICAL SATELLITE ASTRO-C (GINGA)

FLOWN - FY1986
SENSING TECHNIQUE - LINEAR CCD + SLIT
FOV - 50degX50deg 2 AXIS
DETECTOR - TCD102C 2048 PIXCELL
DATA RATE - 0.5 SEC
RESOLUTION - 0.025 DEG
POWER - 2.5W
WEIGHT 2.0Kg

11 D0000

CONTROL MOMENT GYRO - SINGLE GIMBAL

The control moment gyro (CMG) is basically a momentum wheel mounted on gimbals in either one or two axes. This brief deals with the single axis CMG while another will cover the double gimbal CMG. The CMG is run at a constant speed with no need for speed changes. Torques are absorbed, or generated (for maneuvers) by rotating the gimbal axis. Since the angular momentum vector of the CMG resists any change in direction, the spacecraft is essentially being rotated about the wheel spin axis. Gimbal torquer motors can be made powerful enough to permit high rates of reorientation.

CMG designers face two major problems. First, the need to bring power and angle information across the rotating gimbal interface, which is usually accomplished by slip rings, which generally suffer from wearout life and signal noise. Second, design of the wheel bearings is a major challenge since they must last for up to 10 years of continuous or intermittent operation. Usually spacecraft wheel bearings are specially produced ball bearings, with exceptional care given to materials and finish of balls and races and the use of special lubricants. They are enclosed in an evacuated housing and are built to have such low levels of friction that they will run for days after power has been removed. Wheels have been designed for angular momenta in the range of 5 to 5,000 ft-lb-sec (at maximum speed) and can weigh from 10 to 400 pounds, excluding the drive electronics.

Three single gimbal CMGs are required to stabilize a spacecraft while only two double gimbal CMGs will accomplish the same job.

37 D016C

SEE PAGE# D016A FOR DETAILS

42 D018C

SEE PAGE# D018A FOR DETAILS

12 D0000

CONTROL MOMENT GYRO - DOUBLE GIMBAL

(SEE DESCRIPTION OF SINGLE GIMBAL CMG ON CTL # 1206060A01)

Only two double gimbal CMGs are required to stabilize a spacecraft while three single gimbals units are required for the same job.

34 D015B

MOMENTUM WHEEL

MAIN FEATURES:

- 3-AXIS CONTROLLED MAGNETIC BEARING
- GIMBALLING CAPABILITY
- LIGHT WEIGHT

TECHNICAL DATA:

- ANGULAR MOMENTUM	70Nms
- MAXIMUM SPEED	10,000 RPM
- MAXIMUM GIMBAL ANGLE	0.5 DEG
- WEIGHT WITHOUT ELECTRONICS	5.5 kg

39 D017B

SEE PAGE# D017A FOR DETAILS

47 D021D
58 DC28C

SEE PAGE# D028A FOR DETAILS

65 D030C

ENGINEERING TEST SATELLITE-VI (ETS-VI)

* VERIFICATION OF H-II LAUNCH VEHICLE PERFORMANCE
* ESTABLISHMENT OF BASIC TECHNOLOGIES REQUIRED FOR THE BUS SYSTEMS OF A TWO TON CLASS THREE AXIS STABILIZED GEOSTATIONARY SATELLITE FOR USE IN TELECOMMUNICATIONS.
* ORBIT: GEO
  LIFE: 10 YEARS
* LAUNCH DATE/VEHICLE: 1993/ H-II
* EXPERIMENTERS: NASDA, MINISTRY OF POSTS & TELECOMMUNICATIONS, RADIO RESEARCH LABORATORIES, NIPPON
* PRIME CONTRACTOR: TBD

66 D030D

ADEOS - ADVANCED EARTH OBSERVING SATELLITE

MISSION -
* CONTINUITY & ADVANCEMENT OF JAPANESE EARTH OBSERVATION TECHNOLOGIES.
* CONTRIBUTION TO INTERNATIONAL COMMUNITIES
* DEVELOPMENT OF ADVANCED OPTICAL SENSORS
* CONDUCT OF INTER-SATELLITE EARTH OBSERVATION DATA RELAY
* DEVELOPMENT OF A MODULAR & UNIT TYPE SATELLITE

WEIGHT: 3.0 TONS

ATTITUDE CONTROL: THREE AXIS STABILIZED

PAYLOAD: OCTS, AVNIR, AO SENSORS

MISSION LIFE: 3 YEARS

ORBIT: SUN-SYNCHRONOUS SUBRECURRENT (ALTI: 800km)

92 D039F

PLANNING FOR GMS-6 . JMA, THE MARITIME SAFETY AGENCY, AND THE CIVIL AVIATION BUREAU--ALL WITHIN THE MINISTRY OF TRANSPORT--ARE CONSIDERING A COMBINED METEOROLOGICAL/COMMUNICATIONS/SEARCH AND RESCUE MISSION FOR THE NEXT-GENERATION GMS-6 SPACECRAFT. THE POTENTIAL COMMUNICATIONS/SEARCH AND RESCUE COMPONENT WOULD SERVE AN ENVISIONED NATIONAL AVIATION, MARITIME AND LAND TRANSPORT NAVIGATION/TRAFFIC CONTROL/TELECOMMUNICATIONS SYSTEM. NASDA STATED THAT SUCH A COMBINED MISSION WOULD REQUIRE A LARGER "MULTIMISSION" SPACECRAFT, AND THAT THE THREE-AXIS STABILIZED ETS-6 SATELLITE IS SEEN AS A POTENTIAL BUS. THEY WERE QUICK TO MENTION THAT THIS HAS YET TO BE DECIDED, AND THAT A "TRADE OFF STUDY" COULD BE DONE IN WHICH SPIN-STABILIZED TECHNOLOGY WOULD BE CONSIDERED AS ANOTHER OPTION. NASDA ALSO SAID THAT IF A THREE-AXIS STABILIZED BUS WERE CHOSEN, IT WOULD REQUIRE

NO THREE-AXIS COMPATIBLE VISSR IMAGER). THE FUTURE GMS-6 IS TENTATIVELY SCHEDULED FOR LAUNCH IN 1998. NASDA SAID A "PRE-PHASE A" STUDY WOULD BEGIN THIS YEAR, WITH A PHASE A STUDY SOON TO FOLLOW.

13 D0000

REACTION WHEEL

The reaction wheel can be operated in either direction, from zero speed up to the maximum of the driving motor. Disturbance torques are absorbed by changes in wheel speed. It is the change" in wheel speed and "not" the wheel speed itself that generates or counteracts a torque about its axis. This change in wheel speed can be used to rotate the spacecraft about its axis for reorientation maneuvers as well as to absorb disturbance torques. One reaction wheel is needed for each of the three axes. However the limited torque capability of the reaction wheel motors allows only low rates of reorientation.

Disadvantages of reaction wheels include the difficulty of measuring wheel speed accurately when it is near zero, the high motor torque required and bearing problems that result from varying speeds.

33 D015A

REACTION WHEEL

MAIN FEATURES:

- 2-AXIS CONTROLLED MAGNETIC BEARING
- FLAT SHAPE
- HIGH BEARING STIFFNESS

TECHNICAL DATA:

- ANGULAR MOMETUM	+- 7.5 Nms
- MAXIMUM SPEED	+- 3,000 RPM
- DIMENSION	250mm dia x 50mm height
- AXIAL STIFFNESS	3.2 x 10^5 N/m

68 D032A

A Flat Magnetic Bearing Reaction Wheel

A flat magnetic bearing reaction wheel was developed considering the requirement matching. The simplest structured two axis radially controlled magnetic bearing system was applied. The bearing has sufficient stiffness and stable levitation characteristics. A simple structure would be low cost, highly reliable and stable. An advanced higher speed stable operation will be possible by using a magnetic bearing system.

APPENDIX E

IR DETECTORS & FOCAL PLANE ARRAYS (IRDFPA)

1401000000 - IRDFPA - SYSTEM PERFORMANCE

FOCAL PLANE ARRAYS:

- 1401010A02 - ULTRA-VIOLET REGION (UV) CCD
- 1401020A02 - VISIBLE REGION - CCD

IR DETECTORS - PHOTOCONDUCTOR:

- 1401030A02 - SHEET A - Pbs
- 1401030A02 - SHEET B - InSb
- 1401030A02 - SHEET C - HgCdTe
- 1401030A02 - SHEET D - GaAs
- 1401030A02 - SHEET E - DOPED SILICON

IR DETECTORS - LINEAR ARRAY:

- 1401030A02 - SHEET F - PHOTODIODE
- 1401030A02 - SHEET G - CHARGED COUPLED DEVICE

IR DETECTORS - FOCAL PLANE ARRAY:

- 1401030A02 - SHEET H - HYBRID
- 1401030A02 - SHEET I - CCD

1401030A02 - SHEET J - IR DETECTOR - VIDICON

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** *** SUB-TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS								
14010 00000	A	BL		B	E0000		Y	
14010 00000	A	JA	B	P	E051C	P	Y	FUJITSU LTD
14010 00000	A	JA	B	P	E051D	P	Y	FUJITSU LTD
14010 00000	A	JA	E	P	E052A	P	Y	FUJITSU TOKKI SYSTEMS LTD (TSL)
14010 00000	A	JA	E	P	E064A	P	Y	FUJITSU, LTD.
14010 00000	A	JA	E	P	E058L	P	Y	HITACHI, LTD., CENTRAL LABORATORY
14010 00000	A	JA	E	P	E061A	P	Y	MITSUBISHI ELECTRIC COPRORATION
14010 00000	A	JA	B	P	E033C	P	Y	NATIOANAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 00000	A	JA	B	P	E057C	P	Y	NATIOANL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 00000	A	JA	E	P	E057A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 00000	A	JA	E	P	E057B	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 00000	A	JA	E	P	E057D	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 00000	A	JA	E	P	E067A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 00000	A	JA	E	P	E043A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 00000	A	JA	E	P	E043B	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)

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14010 00000	A	JA	E	P	E046A	P	Y	NEC CORPORATION
14010 00000	A	JA	E	P	E056D	P	Y	NEC CORPORATION
14010 00000	A	JA	E	P	E045A	P	Y	THE DEFENSE AGENCY'S TECHNICAL RESEARCH & DEVELOPMENT INSTITUTE (TRDI)
14010 00000	A	JA	E	P	E047A	P	Y	THE UNIVERSITY OF TOKYO'S RESEARCH CENTER FOR ADVANCED SCIENCE AND TECHNOLOGY
14010 00000	A	JA	E	P	E056C	P	Y	TOSHIBA CORPORATION
14010 00000	A	JA	E	P	E055A	P	Y	UNIVERSITY OF TOKYO, CENTER FOR LEADING-EDGE SCIENCE & TECHNOLOGY RESEARCH
14010 00000	A	JA	E	P	E049A	P	Y	UNKNOWN
14010 00000	A	JA	E	S	E049B	E051C	Y	UNKNOWN
14010 00000	A	JA	E	P	E049C	P	Y	UNKNOWN
14010 00000	A	JA	E	S	E049D	E067A	Y	UNKNOWN

** *** SUB-TECHNOLOGY: FOCAL PLANE ARRAYS - ULTRA-VOILET REGION (UV) - CCD

CTL #	SHEET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
14010 10A02	A	BL		B	E0000		Y	

** *** SUB-TECHNOLOGY: FOCAL PLANE ARRAYS - VISIBLE REGION - CCD

CTL #	SHEET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
14010 20A02	A	BL		B	E0000		Y	

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1401020A02	A	JA	C	P	E028B	P	Y	INSTITUTE OF ASTRONAUTICAL AND SCIENCES
1401020A02	A	JA	C	P	E062A	P	Y	NEC CORPORATION
1401020A02	A	JA	C	P	E034A	P	Y	NEC CORPORATION - SPACE DEVELOPMENT DIVISION - YOKOHAMA PLANT
1401020A02	A	JA	E	P	E048A	P	Y	TOSHIBA CORPORATION
** *** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - PbS								
1401030A02	A	BL		B	E0000		Y	
1401030A02	A	JA	C	P	E005A	P	Y	GEOLOGICAL SURVEY OF JAPAN
1401030A02	A	JA	C	P	E029A	P	Y	HAMAMATSU PHOTONICS KK
1401030A02	A	JA	C	P	E029B	P	Y	HAMAMATSU PHOTONICS, KK
1401030A02	A	JA	C	P	E029C	P	Y	HAMAMATSU PHOTONICS, KK
1401030A02	A	JA	B	P	E029D	P	Y	HAMAMATSU PHOTONICS, KK
1401030A02	A	JA	C	P	E058A	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
1401030A02	A	JA	B	P	E058B	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
1401030A02	A	JA	C	P	E066A	P	N	SHIZUOKA UNIVERSITY, FACULTY OF ENGINEERING
1401030A02	A	JA	B	P	E066B	P	N	SHIZUOKA UNIVERSITY, FACULTY OF ENGINEERING

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - InSb								
14010 30A02	B	BL		B	E0000		Y	
14010 30A02	B	JA	C	P	E032A	P	N	HAMAMATSU PHOTONICS KK
14010 30A02	B	JA	C	P	E058G	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
** *** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - HgCdTe								
14010 30A02	C	BL		B	E0000		Y	
14010 30A02	C	JA	C	S	E004B	E009B	Y	EARTH OBSERVATION CENTER NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	C	JA	C	P	E009C	P	N	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	C	JA	C	S	E051A	E009B	N	FUJITSU LTD
14010 30A02	C	JA	C	P	E032B	P	N	HAMAMATSU PHOTONICS KK
14010 30A02	C	JA	C	P	E058D	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	C	JA	D	P	E031.	P	Y	MITSUBISHI ELECTRONICS CORP, OPTOELECTRONICS & MICROWAVE DEVICES R&D LABORATORY
14010 30A02	C	JA	D	P	E033A	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	C	JA	C	S	E027E	E009B	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - GaAs								
14010 30A02	D	BL		B	E0000		Y	
** *** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - DOPED SILICON								
14010 30A02	E	BL		B	E0000		Y	
14010 30A02	E	JA	C	S	E004C	E009B	Y	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	E	JA	C	P	E009B	P	N	EARTH OBSEVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	E	JA	D	P	E005B	P	Y	GEOLOGICAL SURVEY OF JAPAN
14010 30A02	E	JA	D	P	E058C	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	E	JA	D	P	E058E	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	E	JA	D	P	E058F	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	E	JA	C	P	E058H	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	E	JA	C	P	E058I	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	E	JA	C	P	E058J	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
14010 30A02	E	JA	C	P	E026A	P	Y	MITSUBISHI ELECTRIC CORP., LSI R&D LAB
** *** SUB-TECHNOLOGY: IR DETECTOR - LINEAR ARRAY - PHOTODIODE								
14010 30A02	F	BL		B	E0000		Y	

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
14010 30A02	F	JA	C	P	E059B	P	N	FUJITSU LTD
14010 30A02	F	JA	D	P	E059C	P	N	FUJITSU LTD
14010 30A02	F	JA	C	P	E059A	P	N	FUJITSU LTD.
14010 30A02	F	JA	C	P	E003A	P	Y	INSTITUTE OF ENGINEERING MECHANICS, UNIVERSITY OF TSUKUBA
14010 30A02	F	JA	C	P	E003B	P	N	INSTITUTE OF ENGINEERING MECHANICS, UNIVERSITY OF TSUKUBA
14010 30A02	F	JA	C	P	E027D	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	F	JA			E066C		Y	SHIZUOKA UNIVERSITY, FACULTY OF ENGINEERING
** *** SUB-TECHNOLOGY: IR DETECTORS - LINEAR ARRAY - CHARGE COUPLED DEVICE								
14010 30A02	G	BL		B	E0000		Y	
14010 30A02	G	JA	C	P	E009A	P	N	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	G	JA	C	S	E004A	E009A	Y	EARTH OBSERVATION CENTER,NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	G	JA	B	S	E056B	E056A	Y	FUJITSU LIMITED
14010 30A02	G	JA	B	S	E024B	E056A	Y	FUJITSU LTD.
14010 30A02	G	JA	C	S	E013A	E009A	Y	GEOGRAPHICAL SURVEY INSTITUTE OF JAPAN

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
14010 30A02	G	JA	C	S	E013B	E009A	Y	GEOGRAPHICAL SURVEY INSTITUTE OF JAPAN
14010 30A02	G	JA	E	P	E058K	P	Y	HITACHI LTD. CENTRAL LABORATORY
14010 30A02	G	JA	C	S	E001A	E022A	Y	MINISTRY OF INTERNATIONAL TRADE
14010 30A02	G	JA	B	P	E056A	P	Y	MISUBISHI ELECTRIC CORPORATION (MELCO)
14010 30A02	G	JA	B	S	E024A	E056A	Y	MITSUBISHI ELECTR CORPORATION (MELCO)
14010 30A02	G	JA	B	P	E002A	P	N	MITSUBISHI ELECTRIC COMPANY
14010 30A02	G	JA	C	S	E021A	E009A	Y	NATIONAL SPACE DEVELOPMENT AGENCY
14010 30A02	G	JA	C	S	E021B	E009A	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	G	JA	C	S	E021B	E009A	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	G	JA	C	S	E021C	E009A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	G	JA	C	S	E021D	E009A	N	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
14010 30A02	G	JA	C	S	E001B	E002A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	G	JA	C	S	E027A	E009A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	G	JA	C	S	E027B	E009A	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A02	G	JA	C	S	E016A	E022A	Y	NEC CORPORATION

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: IR DETECTOR - VIDICON								
14010 30A02	J	BL		B	E0000		Y	
14010 30A02	J	JA	B	P	E054A	P	Y	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION
14010 30A02	J	JA	B	P	E054B	P	Y	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION
14010 30A02	J	JA	B	P	E054C	P	Y	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION
14010 30A02	J	JA	B	P	E054D	P	Y	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION
14010 30A02	J	JA	D	P	E065A	P	Y	RADIO RESEARCH LABORATORIES
14010 30A02	J	JA	C	P	D033D	P	Y	TOSHIBA CORPORATION
** *** SUB-TECHNOLOGY: IR DETECTOR - CRYOGENIC COOLERS								
14010 30A04	A	BL		B	E0000		Y	
14010 30A04	A	JA	E	P	E009D	P	N	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A04	A	JA	C	P	E050A	P	Y	FUJITSU LTD, SPACE DEVELOPMENT PROMOTION GROUP'
14010 30A04	A	JA	E	S	E051B	E009D	Y	FUJITSU LTD.
14010 30A04	A	JA	D	P	E029E	P	Y	HAMAMATSU PHOTONICS, KK
14010 30A04	A	JA	E	P	E032C	P	N	HAMAMATSU PHOTONICS, KK

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14010 30A02	G	JA	C	S	E016B	E022A	Y	NEC CORPORATION
14010 30A02	G	JA	C	S	E016C	E022A	Y	NEC CORPORATION
14010 30A02	G	JA	C	P	E034B	P	Y	NEC CORPORATION - SPACE DEVELOPMENT DIVISION - YOKOHAMA PLANT
14010 30A02	G	JA	C	P	E022A	P	Y	SCIENCE AND TECHNOLOGY AGENCY
14010 30A02	G	JA	C	S	E023A	E022A	Y	UINKNOWN
** *** SUB-TECHNOLOGY: IR DETECTOR - FOCAL PLANE ARRAY - HYBRID								
14010 30A02	H	BL		B	E0000		Y	
14010 30A02	H	JA	B	P	E025A	P	Y	UNIVERSITY OF TSUKUBA, INSTITUTE OF MATERIAL SCIENCE
** *** SUB-TECHNOLOGY: IR DETECTOR - FOCAL PLANE ARRAY - CCD								
14010 30A02	I	BL		B	E0000		Y	
14010 30A02	I	JA	B	P	E060A	P	Y	FUJITSU LTD
14010 30A02	I	JA	D	P	E028A	P	Y	INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCES
14010 30A02	I	JA	C	P	E030A	P	Y	MITSUBISHI ELECTRIC CORPORATION, LSI R & D LABORATORY
14010 30A02	I	JA	B	P	E044A	P	Y	NEC CORPORATION
14010 30A02	I	JA	C	P	E062B	P	Y	NEC CORPORATION

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
14010 30A04	A	JA	B	P	D025A	P	Y	HITACHI, LTD.
14010 30A04	A	JA	C	P	E003C	P	Y	INSTITUTE OF ENGINEERING MECHANICS, UNIVERSITY OF TSUKUBA
14010 30A04	A	JA	B	P	D025A	P	Y	MITSUBISHI ELECTRIC CORP.
14010 30A04	A	JA	E	P	E033B	P	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)
14010 30A04	A	JA	E	S	E027C	E009D	Y	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN, (NASDA)
14010 30A04	A	JA			E063A		Y	SEE MEMO

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS							
14010 00000 A IRDFP A	SPECTRAL RANGE --- uM (MICROMETERS) --- IMPR. DIR:	BAND NUMBER --- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF
** ******************** SUB-TECHNOLOGY: FOCAL PLANE ARRAYS - ULTRA-VOILET REGION (UV) - CCD							
14010 10A02 A IRDFP A	NUMBER OF DETECTORS --- UNITS --- IMPR. DIR: H	UNIT CELL SIZE --- uM (MICROMETERS) --- IMPR. DIR: L	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	CUTOFF WAVELENGTH --- uM (MICROMETERS) --- IMPR. DIR: X	OPERATING TEMPERATURE --- DEG KELVIN --- IMPR. DIR: H	DETECTOR MATERIAL --- CHEMICAL FORMULATION --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: FOCAL PLANE ARRAYS - VISIBLE REGION - CCD							
14010 20A02 A IRDFP A	NUMBER OF DETECTORS --- UNITS --- IMPR. DIR: H	UNIT CELL SIZE --- uM (MICROMETERS) --- IMPR. DIR: L	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	CUTOFF WAVELENGTH --- uM (MICROMETERS) --- IMPR. DIR: X	OPERATING TEMPERATURE --- DEG KELVIN --- IMPR. DIR: H	DETECTOR MATERIAL --- CHEMICAL FORMULATION --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - PbS							
14010 30A02 A IRDFP A	SPECTRAL RANGE --- uM (MICROMETERS) --- IMPR. DIR: X	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	TIME CONSTANT --- MSEC --- IMPR. DIR: L	OPERATING TEMP --- DEG KELVIN --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP

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CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - InSb							
14010 30A02 B IRDFP A	SPECTRAL RANGE --- uM (MICROMETERS) --- IMPR. DIR: X	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	TIME CONSTANT --- uSEC --- IMPR. DIR: L	OPERATING TEMP --- DEG KELVIN --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - HgCdTe							
14010 30A02 C IRDFP A	SPECTRAL RANGE --- uM (MICROMETERS) --- IMPR. DIR: X	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	TIME CONSTANT --- NSEC --- IMPR. DIR: L	OPERATING TEMP --- DEG KELVIN --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - GaAs							
14010 30A02 D IRDFP A	SPECTRAL RANGE --- uM (MICROMETERS) --- IMPR. DIR: X	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	TIME CONSTANT --- NSEC --- IMPR. DIR: L	OPERATING TEMP --- DEG KELVIN --- IMPR. DIR: H	--- --- IMPR. DIR:	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - DOPED SILICON							
14010 30A02 E IRDFP A	DOPANT --- NONE --- IMPR. DIR: X	SPECTRAL RANGE --- uM (MICROMETERS) --- IMPR. DIR: X	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	TIME CONSTANT --- NSEC --- IMPR. DIR: L	OPERATING TEMP --- DEG KELVIN --- IMPR. DIR: H	--- --- IMPR. DIR:	COMP

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TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS

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** ******************** SUB-TECHNOLOGY: IR DETECTOR - LINEAR ARRAY - PHOTODIODE							
14010 30A02 F IRDFP A	NUMBER OF DETECTORS --- UNITS --- IMPR. DIR: H	UNIT CELL SIZE --- uM (MICROMETERS) --- IMPR. DIR: L	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	CUTOFF WAVELENGTH --- uM (MICROMETERS) --- IMPR. DIR: X	OPERATING TEMPERATURE --- DEG KELVIN --- IMPR. DIR: H	DETECTOR MATERIAL --- CHEMICAL FORMULATION --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTORS - LINEAR ARRAY - CHARGE COUPLED DEVICE							
14010 30A02 G IRDFP A	NUMBER OF DETECTORS --- UNITS --- IMPR. DIR: H	UNIT CELL SIZE --- uM (MICROMETERS) --- IMPR. DIR: L	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	CUTOFF WAVELENGTH --- uM (MICROMETERS) --- IMPR. DIR: X	OPERATING TEMPERATURE --- DEG KELVIN --- IMPR. DIR: H	DETECTOR MATERIAL --- CHEMICAL FORMULATION --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - FOCAL PLANE ARRAY - HYBRID							
14010 30A02 H IRDFP A	NUMBER OF DETECTORS --- UNITS --- IMPR. DIR: H	UNIT CELL SIZE --- uM (MICROMETERS) --- IMPR. DIR: L	BUTTABLE ARRAYS --- NO. OF SIDES --- IMPR. DIR: H	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	CUTOFF WAVELENGTH --- uM (MICROMETERS) --- IMPR. DIR: X	OPERATING TEMPERATURE --- DEG KELVIN --- IMPR. DIR: H	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - FOCAL PLANE ARRAY - CCD							
14010 30A02 I IRDFP A	NUMBER OF DETECTORS --- UNITS --- IMPR. DIR: H	UNIT CELL SIZE --- uM (MICROMETERS) --- IMPR. DIR: L	DETECTIVITY (D*) --- CM Hz 1/2W^-1 --- IMPR. DIR: H	CUTOFF WAVELENGTH --- uM (MICROMETERS) --- IMPR. DIR: X	OPERATING TEMPERATURE --- DEG KELVIN --- IMPR. DIR: H	DETECTOR MATERIAL --- CHEMICAL FORMULATION --- IMPR. DIR: X	COMP

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** ******************** SUB-TECHNOLOGY: IR DETECTOR - VIDICON							
14010 30A02 J IRDFP A	WAVELENGTH RANGE --- NANOMETERS (nm) --- IMPR. DIR: X	TARGET MATERIAL --- NONE --- IMPR. DIR: X	DARK CURRENT --- NANO AMPERES --- IMPR. DIR: L	GAMMA --- NONE --- IMPR. DIR: H	SIGNAL CURRENT --- nA --- IMPR. DIR: H	LIMITING RESOLUTION AT CENTER --- TV LINES --- IMPR. DIR: H	COMP
** ******************** SUB-TECHNOLOGY: IR DETECTOR - CRYOGENIC COOLERS							
14010 30A04 A IRDFP A	COEFFICIENT OF PERFORMANCE (COP) --- RATIO COOL/POWER --- IMPR. DIR: H	COOLER CAPACITY --- WATTS --- IMPR. DIR: H	POWER REQUIREMENTS --- WATTS --- IMPR. DIR: L	VIBRATION LEVEL --- NONE --- IMPR. DIR: L	TECHNOLOGY TYPE --- TYPE NAME --- IMPR. DIR: X	--- --- IMPR. DIR:	COMP

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS												
14010 00000 A IRDFP A 84	B	FUJITSU LTD ---- 1015, KAMIKODANAKA, NAKAHARA-KU, KAWASKI 211, JAPAN ---- T. YAMASHITA, K. ISHIZAKA & T. UCHIYAMA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	0.5 ---- VISIBL E BAND-V TIR 1 BAND ONLY	----	----	----	----	----	JDG/VOL 25 #1/009 03/15/8 9 E051C / / JA
14010 00000 A IRDFP A 85	B	FUJITSU LTD ---- 1015, KAMIKODANAKA, NAKAHARA-KU, KAWASKI 211, JAPAN ---- T.YAMASHITA, K. ISHIZAKA, T. UCHIYAMA ----	---- ---- ----	---- ---- ----	Y A FP U	.51 ---- VISIBL E BAND MESSR & .61-1. 10 INFRAR ED BAND MESSR FOR MOS 1	----	----	----	----	----	JDG/VOL 25 #1/009 03/15/8 9 E051D / / JA
14010 00000 A IRDFP A 86	E	FUJITSU TOKKI SYSTEMS LTD (TSL) ---- ?, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	----	----	----	JDH/TSL BROCHUR E/006 / / E052A / / JA
14010 00000 A IRDFP A 122	E	FUJITSU, LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- GENERAL INFORMATION-SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	----	----	----	JAJ/12- 15-89/0 48 12/15/8 9 E064A 01/01/7 2 JA

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14010 00000 A IRDFP A 113	E	HITACHI, LTD., CENTRAL LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- NORIO KOIKE ---- FUTURE TRENDS REGARDING THIS TECHNOLOGY AS REPORTED BY THIS AUTHOR	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JAJ/10-27-89/0 33 10/27/8 9 E058L / / JA
14010 00000 A IRDFP A 118	E	MITSUBISHI ELECTRIC COPRORATION ---- MITSUBISHI DENKI BLDG., 2-3, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A PE U	---- ARTICL E CONTAI NS ONLY INFORM ATION PERTAI NING TO THE COMPAN IES PARTIC IPATIO N IN THIS TECHNO LOGY	----	----	----	----	----	JAX/#93 8/005 10/30/8 9 E061A / / JA
14010 00000 A IRDFP A 65	B	NATIOANAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	NEC CORPORATION ---- NEC BUILDING, 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- GMS-3 PRIME CONTRACTOR	---- ---- ----	Y A FP U	0.50 - 0.75 ---- PHOTO MULTIP LIER TUBE DETECT OR IN VISIBL E SPECTR	----	----	----	----	----	JCT/GMS -3 BROCH/0 13 / / E033C 01/01/8 4 JA

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14010 00000 A IRDFP A 100	B	NATIOANL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI & KOJIMA ----	---- ---- ----	---- ---- ----	Y P RD U	0.55 -12.5 ---- GMS-5 WAVELENGTHS - 0.55-0.90, 10.5-11.5, 11.5-12.5 6.5-7.0	----	----	----	----	----	JBE/MSG 18800/004 11/06/89 E057C 01/01/93 JA
14010 00000 A IRDFP A 98	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO - KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI, KOJIMA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- GMS SATELLITE INFRARED TECHNOLOGY	----	----	----	----	----	JBE/MSG 18800/002 / / E057A / / JA
14010 00000 A IRDFP A 99	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI & KOJIMA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- GMS-4 - VISSR	----	----	----	----	----	JBE/MSG 18800/004 11/06/89 E057B 10/06/89 JA

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14010 00000 A IRDFP A 101	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSCHO, MINATO-KU, TOKYO 105, JAPAN ---- TANAKA, YAMAMOTO, TOGASHI, KOJIMA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	---- GMS-6 - VISSR	----	----	----	----	----	JBE/MSG 18800/0 05 11/06/8 9 E057D / / JA
14010 00000 A IRDFP A 59	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 150, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JAJ/08-25-89/0 17 08/25/8 9 E067A / / JA
14010 00000 A IRDFP A 68	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- YUGI MIYACHI & YASUSHI HORIKAWA ----	NASDA LOS ANGELES OFFICE ---- 300 SOUTH GRAND AVE., SUITE 2760, LOS ANGELES, CA 90071 ---- YOSHIKAZU KAMIYA ----	---- ---- ----	Y P RD U	TBD ---- ERS-1 - VNR	04 ----	----	----	----	----	JBT/VOL III/162 5 / / E043A 01/01/9 1 JA
14010 00000 A IRDFP A 69	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- YUJI MIYACHI & YASUSHI HORIKAWA ----	NASDA LOS ANGELES OFFICE ---- 300 SOUTH GRAND AVE, SUITE 2760, LOS ANGELES, CA. 90071 ---- YOSHIKAZU KAMIYA ----	---- ---- ----	Y P RD U	TBD ---- ERS-1 SWIR	3 TO 4 ----	----	----	----	----	JBT/VOL III/162 5 / / E043B 01/01/9 1 JA

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14010 00000 A IRDFP A 74	E	NEC CORPORATION ---- NEC BUILDING, 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	KAWASAKI HEAVY INDUSTRIES, LTD. ---- 4-1, HAMAMATSU-CHO, 2-CHOME, MINATO-KU, TOKYO, JAPAN ---- ----	---- ---- ----	Y P RD U	08-080 ----	----	----	----	----	----	JAA/VOL 4 #8/002 09/08/8 9 E046A 01/01/9 3 JA
14010 00000 A IRDFP A 97	E	NEC CORPORATION ---- SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	---- ADVANC ED TECHNO LOGY IN INFRAR ED TECHNO LOGY	----	----	----	----	----	JAJ/10-23-89/0 24 10/23/8 9 E056D / / JA
14010 00000 A IRDFP A 73	E	THE DEFENSE AGENCY'S TECHNICAL RESEARCH & DEVELOPMENT INSTITUTE (TRDI) ---- ?, JAPAN ---- ---- SEE MEMO	MITSUBISHI HEAVY INDUSTRIES (MHI) ---- 5-1, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y P RD U	----	----	----	----	----	----	JAA/VOL 4 #4/005 03/31/8 9 E045A 01/01/9 1 JA
14010 00000 A IRDFP A 75	E	THE UNIVERSITY OF TOKYO'S RESEARCH CENTER FOR ADVANCED SCIENCE AND TECHNOLOGY ---- TOKYO, JAPAN ---- ----	NIPPON CARBON CO., LTD. ---- 6-1, HATCHOBORI 2-CHOME, CHUO-KU, TOKYO 104, JAPAN ---- ----	SOGO KEIBI HOSHO COMPANY ---- ?, JAPAN ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAA/VOL 4 #8/002 09/08/8 9 E047A 01/17/8 9 JA

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14010 00000 A IRDFP A 96	E	TOSHIBA CORPORATION ---- 1-1, SHIBAUARA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	---- ADVANCED TECHNOLOGIY IN FLIR	----	----	----	----	----	JAJ/10-23-89/024 10/23/89 E056C / / JA
14010 00000 A IRDFP A 93	E	UNIVERSITY OF TOKYO, CENTER FOR LEADING-EDGE SCIENCE & TECHNOLOGY RESEARCH ---- TOKYO, JAPAN ---- H. YANAGIDA ----	NIPPON CARBON CO. LTD., ---- 6-1, HATCHOBORI 2-CHOME, CHUO-KU, TOKYO 104, JAPAN ---- M.FUJII ---- RESPONSIBLE FOR MANUFACTURING	SOGO KEIBI HOSHO CO., LTD ---- ?, JAPAN ---- T.MURAI ---- MARKETING	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAJ/10-23-89/009 10/23/89 E055A / / JA
14010 00000 A IRDFP A 77	E	UNKNOWN ---- ---- ---- ARTICLE REFLECTS NO AUTHOR OR ORIGINATOR	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JDE/10-01-89/020 10/01/89 E049A 08/01/89 JA
14010 00000 A IRDFP A 79	E	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHOR NOT INDICATED IN ARTICLE	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JDE/10-01-89/028 10/01/89 E049C 01/01/92 JA

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** ############### SUB-TECHNOLOGY: FOCAL PLANE ARRAYS - VISIBLE REGION - CCD												
14010 20A02 A IRDFP A 51	C	INSTITUTE OF ASTRONAUTICAL AND SCIENCES ---- 4-6-1, KOMABA, MEGURO-KU, TOKYO 153, JAPAN ---- R.AKIBA & K. UESUGI ----	---- ---- ----	---- ---- ----	Y P DT U	---- PUSHBR OOM WITH A TWO DIMENS IONAL CCD ARRAY IN THE VISIBL E AND INFRAR ED RANGES	----	----	0.35 ---- VISIBL E RANGE	----	----	JBT/VOL I/0261 10/26/8 6 E026B / / JA
14010 20A02 A IRDFP A 119	C	NEC CORPORATION ---- NEC BLDG., 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	4096 ----	----	----	0.52-0 .86 ---- 3 BANDS	----	----	JAJ/01-02-90/0 03 01/02/9 0 E062A 07/01/8 9 JA
14010 20A02 A IRDFP A 66	C	NEC CORPORATION - SPACE DEVELOPMENT DIVISION - YOKOHAMA PLANT ---- 4035, IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	02048 ----	----	----	0.50 - 0.75 ----	----	----	JCX/BRO CHURE/0 01 / / E034A / / JA
14010 20A02 A IRDFP A 76	E	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MIANTO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	----	----	----	JAA/VOL 3 #9/008 10/30/8 8 E046A / / JA

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** ############### SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - PbS												
14010 30A02 A IRDFP A 26	C	GEOLOGICAL SURVEY OF JAPAN ---- HIGASHI 1-1-3, TSUKUBA, IBARAKI 305, JAPAN ---- YASUSHI YAMAGUCHI & ISAO SATO ----	OPTICAL SCIENCE COMPANY LTD. ---- NAKANO-KAMIMACHI 3-20-4, HACHIJI, TOKYO 192, JAPAN ---- TSUTOMU OHKURA ----	---- ---- ----	Y A DT U	0.4 -2.5 ---- VNIR & SWIR, 8 BANDS, FIELD RADIOM ETER	----	----	----	----	----	JAJ/01-26-89/0 231 01/26/8 9 E005A / / JA
14010 30A02 A IRDFP A 52	C	HAMAMATSU PHOTONICS KK ---- 1126, ICHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- SALES CATALOG ON PbSe & Pbs IR DETECTORS	---- ---- ----	---- ---- ----	Y A FP U	1-3 ---- AF SERIES	1.0 x 10^11 ----	0.25 ---- 250um	0338.1 5 ----	----	----	JBX/09-01-89/0 03 09/01/8 9 E029A / / JA
14010 30A02 A IRDFP A 53	C	HAMAMATSU PHOTONICS, KK ---- 1126, INCHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- SALES CATALOG - PbSe & Pbs IR DETECTORS	---- ---- ----	---- ---- ----	Y A FP U	01 - 03 ---- AF SERIES	1.0 x 10^11 ----	.25 ---- 250um	0338.1 5 ---- 65 DEG. C	----	----	JBX/09-01-89/0 05 09/01/8 9 E029B / / JA
14010 30A02 A IRDFP A 54	C	HAMAMATSU PHOTONICS, KK ---- 1126, INCHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- SALES CATALOG - PbSe & Pbs IR DETECTORS	---- ---- ----	---- ---- ----	Y A FP U	01 - 03.5 ---- AT2 SERIES	2.5 x 10^11 ----	01 ---- 1000um	0338.1 5 ---- 65 DEG. C AT MAX PERFOR MANCE LEVEL	----	----	JBX/09-01-89/0 09 09/01/8 9 E029C / / JA

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14010 30A02 A IRDFP A 55	B	HAMAMATSU PHOTONICS, KK ---- 1126, ICHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- SALES CATALOG - PbSe & Pbs IR DETECTORS	---- ---- ----	---- ---- ----	Y A FP U	01 - 05 ---- BT2 SERIES PbSe DETECT OR	1.3 x 10^10 ----	.012 ----	0338.1 5 ---- AT MAX PERFOR MANCE	----	----	JBX/09- 01-89/0 17 09/01/8 9 E029D / / JA
14010 30A02 A IRDFP A 102	C	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	1-3 ---- PHOTOI NDUCTI ON TYPE	?x10^9 ----	----	300 ----	----	----	JAJ/10- 27-89/0 23 10/27/8 9 E058A / / JA
14010 30A02 A IRDFP A 103	B	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ----	---- ---- ----	---- ---- ----	Y P RD U	1-4.5 ---- METRIA L PbSe PHOTOI NDUCTI ON TYPE	?x10^9 ----	----	300 ----	----	----	JAJ/10- 27-89/0 23 10/27/8 9 E058B / / JA
14010 30A02 A IRDFP A 124	C	SHIZUOKA UNIVERSITY, FACULTY OF ENGINEERING ---- 5-1, JOHOKU 3 CHOME, HAMAMATSU 432, JAPAN ---- A.ISHIDA ---- TEAMED WITH J.MASEK, H.ZOGG, C.MAISSEN & S.BLUNIER OF THE SWISS INSTITUTE OF TECH.	---- ---- ----	---- ---- ----	N A DT U	3.4 ---- PHOTOV OLTAIC IR SENSOR	2x10^1 0 ---- CM SQ.RT HZ/W	----	200 ----	----	----	JAG/VOL 11 #1/012 01/01/9 0 E066A / / JA

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14010 30A02 A IRDFP A 125	B	SHIZUOKA UNIVERSITY, FACULTY OF ENGINEERING ---- 5-1, JOHOKU 3 CHOME, HAMAMATSU 432, JAPAN ---- A.ISHIDA ---- TEAMED WITH J.MASEK, H.ZOOG, C.MAISSEN & S. BLUNIER OF THE SWISS FEDERAL INSTITUTE OF TECHNOLOGY	---- ---- ----	---- ---- ----	N A DT U	4 ---- PHOTOVOLTAIC IR SENSOR	1x10^13 ---- cm SQ.RT. HZ/W	----	84 ----	----	----	JAG/VOL11 #1/012 01/01/90 E066B / / JA

** ############### SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - InSb

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 B IRDFP A 60	C	HAMAMATSU PHOTONICS KK ---- 1126, INCHINO-CHO, HAMAMASTU CITY, 435 JAPAN ---- ---- INFRARED DETECTORS CATALOG	---- ---- ----	---- ---- ----	N A FP U	02-05.5 ---- IR CUTOFF WAVELENGTH 3.6	2X10^10 ----	----	077 ----	----	----	JBY/09-01-89/018 09/01/89 E032A / / JA
14010 30A02 B IRDFP A 108	C	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	2-5 ---- PHOTOVOLTAIC TYPE	?x10^10 ----	----	077 ----	----	----	JAJ/10-27-89/023 10/27/89 E058G / / JA

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** *************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - HgCdTe												
14010 30A02 C IRDFP -A 36	C	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- NASDA ----	---- ---- ----	---- ---- ----	N A FP U	06.0-1 2.5 ---- VTIR - THERMAL INFRARED BANDS	----	----	----	----	----	JBP/03-01-86/06 03/01/86 E009C 02/17/86 JA
14010 30A02 C IRDFP A 61	C	HAMAMATSU PHOTONICS KK ---- 1126, INCHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- INFRARED CATALOG	---- ---- ----	---- ---- ----	N A FP U	02 - 12 ----	2 x 10^10 ----	----	077 ----	----	----	JAY/09-01-89/019 09/01/89 E032B / / JA
14010 30A02 C IRDFP A 105	C	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	SEE COMMENTS ---- ---- UEDA ---- REFERENCE MADE TO AN ARTICLE WRITTEN IN 1985 MEETING OF THIS CONFERENCE REGARDING THIS TECHNOLOGY	SEE COMMENT ---- ---- KAKUDA ---- REFENCE MADE TO ARTICLE WRITTEN IN JOURNAL OF THE INSTITUTE OF TV ENG. OF JAPAN	Y P RD U	2-13 ----	?x10^10 ----	----	77 ----	----	----	JAJ/10-27-89/023 10/27/89 E058D / / JA
14010 30A02 C IRDFP A 58	D	MITSUBISHI ELECTRONICS CORP, OPTOELECTRONICS & MICROWAVE DEVICES R&D LABORATORY ---- 4-1, MIZUHARA, ITAMI 664, JAPAN ---- Y. KUMONE, K. IKEDA, W. SUSAKI ----	---- ---- ----	---- ---- ----	Y A DT U	08-14 ----	D blip ----	----	----	----	----	JBV/04-24-89/016 04/24/89 E031. / / JA

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14010 30A02 C IRDFP A 63	D	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	NEC CORPORATION ---- NEC BUILDING, 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- GMS-S PRIME CONTRACTOR	---- ---- ----	Y A FP U	10.5 -12.5 ---- VISSR	----	----	----	----	----	JCT/GMS -3 BROCH/0 13 / / E033A 01/01/8 4 JA

** ############## SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - DOPED SILICON

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PÅR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 E IRDFP A 35	C	EARTH OBSEVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- NASDA ----	---- ---- ----	---- ---- ----	N A FP U	SI-PIN ---- VTIR-V ISIBLE BAND	0.5-0. 7 ----	----	----	----	----	JBP/03- 01-86/0 6 03/01/8 6 E009B 02/19/8 7 JA
14010 30A02 E IRDFP A 27	D	GEOLOGICAL SURVEY OF JAPAN ---- HIGASHI 1-1-3, TSUKUBA, IBARAKI 305, JAPAN ---- YASUSHI YAMAGUCHI & ISAO SATO ----	OPTICAL SCIENCE COMPANY LTD ---- NAKANO-KAMIMACHI 3-20-4, HACHIJO, TOKYO 192, JAPAN ---- TSUTOMU OHKURA ----	---- ---- ----	Y A DT U	SILICO N ----	0.4-2. 5 ---- VNIR & SWIR 7 SPECTR AL BANDS	----	----	----	----	JAJ/01- 26-88/0 231 01/26/8 8 E005B / / JA
14010 30A02 E IRDFP A 104	D	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	InGaAs ----	1-1.6 ----	10^8-1 0^12 ----	----	300 ----	----	JAJ/10- 27-89/0 27 10/27/8 9 E058C / / JA

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14010 30A02 E IRDFP A 106	D	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	Ge ---- PHOTOV OLTAIC TYPE	.6-1.8 ----	10^9-1 0^11 ----	----	300 ----	----	JAJ/10-27-89/0 23 10/27/8 9 E058E / / JA
14010 30A02 E IRDFP A 107	D	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ----	---- ---- ----	---- ---- ----	Y P RD U	InAs ---- PHOTOV OLTAIC TYPE	1-3 ----	?x10^8 -10^12 ----	----	077 ----	----	JAJ/10-27-89/0 23 10/27/8 9 E058F / / JA
14010 30A02 E IRDFP A 109	C	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SUNUGADAI 4-CHOME, CHIYODA-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	Ge:Au ----	1-10 ----	10^8-1 0^12 ----	----	077 ----	----	JAJ/10-27-89/0 23 10/27/8 8 E058H / / JA
14010 30A02 E IRDFP A 110	C	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SUNUGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	Ge:Hg ----	2-14 ----	?x10^1 0 ----	----	04.2 ----	----	JAJ/10-27-89/0 23 10/27/8 9 E058I / / JA

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14010 30A02 E IRDFP A 111	C	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, MINATO-KU, TOKYO 106, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	Si:Ga ----	1-17 ----	?x10^1 0-10^1 2 ----	----	077 ----	----	JAJ/10- 27-89/0 23 10/27/8 9 E058J / / JA
14010 30A02 E IRDFP A 39	C	MITSUBISHI ELECTRIC CORP., LSI R&D LAB ---- 4-1, MIZUHARA, ITAMI 664, JAPAN ---- Y. KOMINE, Y. YOSHIDA, M. HIBINO, Y.HISA ----	MITSUBISHI ELECTRIC CORP., LSI R&D LAB ---- 4-1, MIZUHARA, ITAMI 664, JAPAN ---- R. OHKATA, K. IKEDA, W. SUSAKI ----	MITSUBISHI ELECTRIC CORP., MATERIALS & ELECTRONIC DEVICE LAB ---- 1-1-8, TSUKAGUCHI-HONMACH I, AMAGASAKI, 661, JAPAN ---- K. YASUMURA, AND K. SATO ----	Y A DT U	In ---- CdHgTe DOPED WITH In	08-14 ----	3.1x10 ^10 ----	----	----	----	JBR/12- 14-87/W 7.3 12/14/8 7 E026A / / JA
** *************** SUB-TECHNOLOGY: IR DETECTOR - LINEAR ARRAY - PHOTODIODE												
14010 30A02 F IRDFP A 115	C	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P RD U	64x64 ----	----	----	3-5 ----	----	HYBRID ----	JED/AD A189 294/2-4 0 05/01/8 7 E059B 05/01/8 7 JA
14010 30A02 F IRDFP A 116	D	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- THIS IS A COMMERCIALLY AVAILBLE PHOTOCONDUCTOR, 16 ELEMENT LINEAR ARRAY CAMERA	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	0200 ---- THERMO ELECTR IC COOLER	----	JEQ/AD A189 294/2-4 0 05/01/8 7 E059C / / JA

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14010 30A02 F IRDFP A 114	C	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	----	----	----	3-5 & 10 ----	----	HgCdTe ----	JEO/AD A189 294/2-4 0 05/01/8 7 E059A / / JA
14010 30A02 F IRDFP A 16	C	INSTITUTE OF ENGINEERING MECHANICS, UNIVERSITY OF TSUKUBA ---- TSUKUBA 305, JAPAN ---- SEE COMMENTS FOR ADDITIONAL ORGAIZATIONS ---- NEC CORPORATION, MIDORI-KU, YOKOHAMA 226, JAPAN	INSTITUTE OF SPACE AND ASTRONOMICAL SCIENCE ---- SAGAMIHARA 229, JAPAN ---- SEE COMMENTS FOR ADDITIONAL ORGANIZATION ---- DEPARTMENT OF PHYSICS, NAGOYA UNIVERSITY, NAGOYA 464, JAPAN	SUMITOMO HEAVY INDUSTRIES LTD ---- TOYO, EHIME 799-13, JAPAN ---- ----	Y P RD U	InSb x 24 ---- NEAR IR SPECTR OMETER	----	----	1.3 - 4.1 ----	----	InSb ----	JAT/VOL 29/0553 05/01/8 9 E003A 01/01/9 3 JA
14010 30A02 F IRDFP A 17	C	INSTITUTE OF ENGINEERING MECHANICS, UNIVERSITY OF TSUKUBA ---- TSUKUBA 305, JAPAN ---- SEE COMMENTS FOR ADDITIONAL ORGANIZATION ---- NEC CORPORATION, MIDORI-KU, YOKOHAMA 226, JAPAN	INSTITUTE OF SPACE AND ASTRONOMICAL SCIENCE ---- SAGAMIHARA 229, JAPAN ---- SEE COMMENTS FOR ADDITIONAL ORGANIZATION ---- DEPARTMENT OF PHYSICS, NAGOYA UNIVERSITY, NAGOYA 464, JAPAN	SUMITOMO HEAVY INDUSTRIES LTD, ---- TOYO, EHIME 799-13, JAPAN ---- ----	N P RD U	SiBi/S iGa x 32 ---- MIDDLE IR SPECTR OMETER	----	----	05 - 013.5 ----	----	SiBi/S iGa ----	JAT/VOL 29/0553 05/01/8 9 E003B 01/01/9 3 JA

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14010 30A02 F IRDFP A 48	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- Y.MIYACHI, Y. HORIKAWA, Y. KAMIYA ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	0.5-0.7 ---- MOS-1 VTIR SENSOR -VISBLE WAVELENGTH	----	----	SI - PIN ----	JBT/VOL III/161 1 10/26/86 E027D 04/01/86 JA
** *************** SUB-TECHNOLOGY: IR DETECTORS - LINEAR ARRAY - CHARGE COUPLED DEVICE												
14010 30A02 G IRDFP A 34	C	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- NASDA ----	---- ---- ----	---- ---- ----	N A FP U	02048 ---- MESSR MULTI SPECTRUM ELECTRONIC SELF SCANNING RAIOMETER (MESSR)	----	----	.73-1.10 ---- NEAR INFRARED	----	----	JBP/03-01-86/07 03/01/86 E009A 02/19/87 JA
14010 30A02 G IRDFP A 112	E	HITACHI LTD, CENTRAL LABORATORY ---- 6, KANDA-SURUGADAI 4-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NORIO KOIKE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAJ/10-27-89/023 10/27/89 E058K / / JA

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14010 30A02 G IRDFP A 94	B	MISUBISHI ELECTRIC CORPORATION (MELCO) ---- 2-3 MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	03-05 ----	----	----	JAJ/10-23-89/0 24 10/23/8 9 E056A / / JA
14010 30A02 G IRDFP A 14	B	MITSUBISHI ELECTRIC COMPANY ---- MITSUBISHI DENKI BLDG, 2-3 MARUNOUCHI 2-CHROME, CHIYODA-KU, TOKYO 100 ---- UNKNOWN ----	---- ---- ----	---- ---- ----	N A DT U	260000 ---- MEASURES 1.6cm x 1.2cm	----	----	03 ----	----	----	JAU/IGIH-2858-2695/1 03/04/8 7 E002A / / JA
14010 30A02 G IRDFP A 67	C	NEC CORPORATION - SPACE DEVELOPMENT DIVISION - YOKOHAMA PLANT ---- 4035, IKEBE-CHO, MIDORI-KU, YOKOHAMA 226, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	02048 ----	----	----	0.75 - 1.1 ----	----	----	JCX/BROCHURE/0 01 / / E034B / / JA
14010 30A02 G IRDFP A 24	C	SCIENCE AND TECHNOLOGY AGENCY ---- 2-2-1 KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY ---- 1-3-1 KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y A TT U	04096 ----	----	----	01-03 ---- SWIR, VISIBLE & NEAR INFR-RED BANDS	----	----	JAA/VOL 3 #13/08 01/13/8 9 E022A 01/01/9 1 JA

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** *************** SUB-TECHNOLOGY: IR DETECTOR - FOCAL PLANE ARRAY - HYBRID												
14010 30A02 H IRDFP A 38	B	UNIVERSITY OF TSUKUBA, INSTITUTE OF MATERIAL SCIENCE ---- TSUKUBA SCIENCE CITY 305, JAPAN ---- H.KANAYA & F. HASEGAWA ----	TSUKUBA COLLEGE OF TECHNOLOGY ---- TSUKUBA SCIENCE CITY 305, JAPAN ---- E. YAMAKA ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- TSUKUBA SCIENCE CITY 305, JAPAN ---- T. MORIYAMA & M. NAKAJIMA ----	Y A DT U	----	----	----	----	08-12 ----	077 ----	JAH/VOL 28 #4/L544 04/01/89 E025A 12/24/88 JA
** *************** SUB-TECHNOLOGY: IR DETECTOR - FOCAL PLANE ARRAY - CCD												
14010 30A02 I IRDFP A 117	B	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	16,400 ---- SEE MEMO	----	----	8-12 ----	----	----	JAA/VOL 4 #11/003 12/15/89 E060A / / JA
14010 30A02 I IRDFP A 50	D	INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCES ---- 4-6-1 KOMABA, MEGURO-KU, TOKYO 153, JAPAN ---- R.AKIBA & K. UESUGI ----	---- ---- ----	---- ---- ----	Y P RD U	---- TWO DIMENSIONAL CCD ARRAY WITH OPERATING RANGE OF 0.35-2.5um IN VISIBLE AND INFRARED REGION -PUSHBROOM SCANNI	----	----	02.5 ---- INFRARED RANGE	----	----	JBT/VOL I/0281 10/26/96 E028A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 I IRDFP A 57	C	MITSUBISHI ELECTRIC CORPORATION, LSI R & D LABORATORY ---- 4-1, MIZUHARA, ITAMI, HYOGO 664, JAPAN ---- NAOKI YUTANI, MASAFUMI KIMATA ----	MITSUBISHI ELECTRIC CORPORATION, LSI R & D LABORATORY ---- 4-1, MIZUHARA, ITAMI, HYOGO 664, JAPAN ---- MASAHIKO DENDA, SHUHEI IWADE, ----	MITSUBISHI ELECTRIC CORPORATION, LSI R & D LABORATORY ---- 4-1, MIZUHARA, ITAMI, HYOGO 664, JAPAN ---- NATSURO TSUBOUCHI ----	Y A DT U	512x51 2 ----	26x20u m^2 ----	----	07.3 ----	062 ----	IrSi ----	JBW/12- 06-87/0 124 12/06/8 7 E030A / / JA
14010 30A02 I IRDFP A 72	B	NEC CORPORATION ---- NEC BUILDING, 33-1, SHIBA 5-CHOME MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	160000 ----	----	----	03 - 05 ----	----	----	JAA/VOL 4 #4/003 03/31/8 9 E044A 11/09/8 8 JA
14010 30A02 I IRDFP A 120	C	NEC CORPORATION ---- NEC BLDG., 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	4096 ----	----	----	1.5-2. 4 ----	----	----	JAJ/01- 02-90/0 03 01/02/9 0 E062B 07/01/8 9 JA

SUB-TECHNOLOGY: IR DETECTOR - VIDICON

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1	ORGANIZATION 2	ORGANIZATION 3	ME ST PH SE	PAR 1	PAR 2	PAR 3	PAR 4	PAR 5	PAR 6	SOURCE
14010 30A02 J IRDFP A 89	B	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION ---- 314-5, SHIMOKANZO, TOYOOKA-VILLAGE, IWATA-GUN, SHIZUOKA-KEN, 438-01, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	400-22 00 ---- INFRAR ED VIDICO N-18mm DIA. TYPES	PbO-Pb S ----	05 ----	.8 ----	250 ----	550 ----	JCB/09- 01-89/0 2 09/01/8 9 E054A / / JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 J IRDFP A 90	B	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION ---- 314-5, SHIMOKANZO, YOYOOKA-VILLAGE, IWATA-GUN, SHIZUOKO-KEN, 438-01, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	400-22 00 ---- INFRAR ED VIDICO NS-25m m DIA.TY PES	PbO-Pb S ----	5 ----	0.8 ----	500 ----	24 ----	JCC/09- 01-89/0 11 09/01/8 9 E054B / / JA
14010 30A02 J IRDFP A 91	B	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION ---- 314-5, SHIMOKANZO, TOYOOKA-VILLAGE, IWATA-GUN, SHIZUCKA-KEN, 438-01, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	1100 ---- SILICO N VIDICO N -18 mm DIA TYPE	Si ----	5 ----	1.0 ----	300 ----	500 ----	JCC/09- 01-89/0 13 09/01/8 9 E054C / / JA
14010 30A02 J IRDFP A 92	B	HAMAMATSU PHOTONICS KK, ELECTRON TUBE DIVISION ---- 314-5, SHIMOKANZO, TOYOOKA-VILLAGE, IWATA-GUN, SHIZUOKA-KEN, 438-01, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	300-11 00 ---- SILICO N VIDICO N-25mm DIA.TY PES	Si ----	8 ----	1 ----	360 ----	650 ----	JCC/09- 01-89/0 11 09/01/8 9 E054D / / JA
14010 30A02 J IRDFP A 123	D	RADIO RESEARCH LABORATORIES ---- KOGANEI-SHI, TOKYO 184, JAPAN ---- T.ARUGA, K.ARAKI & T.IGARASHI ---- SEE MEMO: EARTH-TO-SPACE LASER BEAM TRANMISSION FOR SPACECRAFT ATTITUDE CONTROL	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- MINATO-KU, TOKYO 105, JAPAN ---- F.IMAI, Y.YAMAMOTO & H.SAKAGAMI ----	---- ---- ----	Y A FP U	0.48-0 .88 ---- VIDICO N CAMERA	CdSe ----	----	----	----	480 ----	JEZ/VOL 23 #1/0143 01/01/8 4 E065A 03/17/8 3 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	MESTPHSE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 J IRDFP A 88	C	TOSHIBA CORPORATION ---- 1-1, SHIBARU 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	0.48 - 0.88 ---- SEE MEMO	----	----	----	----	----	JDJ/BRO CHURE/0 11 / / D033D / / JA
** ############### SUB-TECHNOLOGY: IR DETECTOR - CRYOGENIC COOLERS												
14010 30A04 A IRDFP A 37	E	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- NASDA ----	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	PASSIV E RADIAT OR ---- FOUND ON MOS-1 SATELL ITE ON VTIR RAIOME TER, RADIAT OR COOLER	----	JBP/03- 01-86/0 8 03/10/8 6 E009D 02/19/8 7 JA
14010 30A04 A IRDFP A 81	C	FUJITSU LTD, SPACE DEVELOPMENT PROMOTION GROUP' ---- 1015, KAMIKODANAKA, NAKAHARA-KU, KAWASAKI 211, JAPAN ---- HIROKAZU OHMAE ----	---- ---- ----	---- ---- ----	Y A FP U	----	001 ----	070 ----	---- SEE MEMO	STIRLI NG ----	----	JDF/08- 22-89/0 01 08/22/8 9 E050A / / JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A04 A IRDFP A 56	D	HAMAMATSU PHOTONICS, KK ---- 1126, ICHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- SALES CATALOG - Pbs & PbSe DETECTORS	---- ---- ----	---- ---- ----	Y A FP U	---- THERMO ELECTR ICALLY COOLED BT2 SERIES PbSe	----	02 ----	----	TH ---- THERMO ELECTR ICALLY COOLED	----	JBX/09-01-89/0 17 09/01/8 9 E029E / / JA
14010 30A04 A IRDFP A 62	E	HAMAMATSU PHOTONICS, KK ---- 1126, INCHINO-CHO, HAMAMATSU CITY, 435 JAPAN ---- ---- INFRARED DETECTOR CATALOG	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	THERMO ELECTR IC COOLER ---- SEE MEMO	----	JBY/09-01-89/0 30 09/01/8 9 E032C / / JA
14010 30A04 A IRDFP A 70	B	HITACHI, LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	----	003 ----	----	----	STERLI NG CYCLE ----	----	JAJ/09-08-89/0 09 09/08/8 9 D025A 07/27/8 7 JA
14010 30A04 A IRDFP A 18	C	INSTITUTE OF ENGINEERING MECHANICS, UNIVERSITY OF TSUKUBA ---- TSUKUBA 305, JAPAN ---- SEE COMMENTS FOR ADDITIONAL ORGANIZATION ---- NEC CORPORATION, MIDORI-KU, YOKOHAMA 226, JAPAN	INSTITUTE OF SPACE AND ASTRONOMICAL SCIENCE ---- SAGAMIHARA 229, JAPAN ---- SEE COMMENTS FOR ADDITIONAL ORGANIZATION ---- DEPARTMENT OF PHYSICS, NAGOYA UNIVERSITY, NAGOYA 464, JAPAN	SUMITOMO HEAVY INDUSTRIES, LTD ---- YOYO, EHIME 799-13, JAPAN ---- ----	Y P RD U	----	0.0067 5 ----	----	LOW TO NONE ----	JOULE THOMPS ON ----	----	JAT/VOL 29/0553 05/01/8 9 E003C 01/01/9 3 JA

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14010 30A04 A IRDFP A 71	B	MITSUBISHI ELECTRIC CORP. ---- MITSUBISHI DENKI BLDG., 2-3, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	----	005 ----	----	----	STERLI NG CYCLE ----	----	JAJ/09-08-89/0 09 09/08/8 9 D025A / / JA
14010 30A04 A IRDFP A 64	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	NEC CORPORATION ---- NEC BUILDING, 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	Y A FP U	---- GMS-3	----	----	----	PASSIV E RADIAT ORS ----	----	JCT/GMS -3BROC. /013 / / E033B 01/01/8 4 JA

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** *************** SUB-TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS												
14010 00000 A E051C IRDFP A 78	E	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHOR NOT IDENTIFIED IN ARTICLE	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JDE/10-01-89/0 22 10/01/8 9 E049B / / JA
14010 00000 A E067A IRDFP A 80	E	UNKNOWN ---- ---- ---- ORIGINATOR OR AUTHOR NOT INDICATED IN THIS ARTICLE	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JDE/10-01-89/0 35 10/01/8 9 E049D / / JA
** *************** SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - HgCdTe												
14010 30A02 C E009B IRDFP A 32	C	EARTH OBSERVATION CENTER NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 1401 OHASHI,HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- K. MAEDA, H. WAKABAYASHI, K. TASAKI ----	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- M. SHIMADA & H. SATO ----	---- ---- ----	Y A FP U	06-12.5 ---- VISIBLE & THERMAL INFRARED RADOMETER (VTIR)	----	----	---- THERMAL INFRARED BANDS, THREE BANDS - 2,3&4	----	----	JAJ/01-29-89/0 58 01/29/8 9 E004B 02/19/8 7 JA
14010 30A02 C E009B IRDFP A 82	C	FUJITSU LTD ---- 1015, KAMIKODANAKA, NAKAHARA-KU, KAWASKI 211, JAPAN ---- T. YAMASHITA, K. ISHIZAKA & T. UCHIYAMA ----	---- ---- ----	---- ---- ----	N A FP U	012.5 ----	----	----	0115 ----	----	----	JDG/VOL 25 #1/009 03/15/8 9 E051A / / JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 C E009B IRDFP A 49	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- Y. MIYACHI, Y.HORIKAWA, Y. KAMIYA ----	---- ---- ----	---- ---- ----	Y A DT U	6.0 - 12.5 ---- MOS-1 VTIR INFRARED REGION	----	----	----	----	----	JBT/VOL III/161 1 10/26/86 E027E 04/01/86 JA
** ############### SUB-TECHNOLOGY: IR DETECTOR - PHOTOCONDUCTOR - DOPED SILICON												
14010 30A02 E E009B IRDFP A 33	C	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- K. MAEDA, H.WAKABAYASHI, K. TASAKI ----	EARTH OBSERVATION CENTER, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- M. SHIMADA AND H. SATO ----	---- ---- ----	Y A FP U	0.5-0.7 ---- MOS-1 VISIBLE & THERMAL INFRARED DETECTOR (VTIR)	----	----	---- VISIBLE BAND BAND 1	----	----	JAJ/01-27-89/058 01/27/89 E004C 02/19/87 JA
** ############### SUB-TECHNOLOGY: IR DETECTORS - LINEAR ARRAY - CHARGE COUPLED DEVICE												
14010 30A02 G E009A IRDFP A 31	C	EARTH OBSERVATION CENTER,NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03,JAPAN ---- K.MAEDA, H.WAKABAYASHI, K.TASAKI ----	EARTH OBSERVATION CENTER, NATIONAL SPACES DEVELOPMENT AGENCY OF JAPAN ---- 1401 OHASHI, HATOYAMA-MACHI, HIKI-GUN, SAITAMA-KEN, 350-03, JAPAN ---- M. SHIMADA AND H.SATO ----	---- ---- ----	Y A FP U	---- MULTI-SPECTRUM ELECTRONIC SELF-SCANNING RADIOMETER (MESSER)	----	----	0.72-1.1 ----	----	----	JAJ/01-26-89/058 01/26/89 E004A 02/19/87 JA

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14010 30A02 G E056A IRDFP A 95	B	FUJITSU LIMITED ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- SEE PAGE-E056A	---- ---- ----	---- ---- ----	Y P RD U	----	----	----	08-12 ----	----	----	JAJ/10-23-89/0 24 10/23/8 9 E056B / / JA
14010 30A02 G E056A IRDFP A 30	B	FUJITSU LTD. ---- MUTSUSHI SHIKATSU-CHO, NISHIKASUGAI-GUN, AICHI 481, JAPAN ---- ----	TECHNICAL R&D INSTITUTE ---- ?, JAPAN ---- ----	---- ---- ----	Y P RD U	----	----	----	08-011 ---- FLIR	----	----	JAX/NO. 917/05 05/22/8 9 E024B / / JA
14010 30A02 G E009A IRDFP A 40	C	GEOGRAPHICAL SURVEY INSTITUTE OF JAPAN ---- KITASATO-1, TSUKUBA-SHI, IBARAKI-KEN, JAPAN ---- IZUMI KAMIYA ----	---- ---- ----	---- ---- ----	Y A FP U	02048 ---- 4-BANDS RANGING FROM VISIBLE REGION TO NEAR INFRARED REGION	----	----	.51 - 1.10 ---- BAND1- .51-.59, BAND2: .61-.69, BAND3: .72-.80, BAND4: .8-1.10	----	----	JAJ/01-26-89/0 20 01/26/8 9 E013A 02/19/8 7 JA
14010 30A02 G E009A IRDFP A 41	C	GEOGRAPHICAL SURVEY INSTITUTE OF JAPAN ---- KITASATO-1, TSUKUBA-SHI, IBARAKI-KEN, JAPAN ---- IZUMI KAMIYA ---- MOS-1 AND MESSER (SEE MEMO)	---- ---- ----	---- ---- ----	Y A FP U	02048 ---- BAND 1 & 2	----	----	0.51 - 0.74 ----	----	----	JAJ/01-26-89/0 20 01/26/8 9 E013B 02/19/8 7 JA

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14010 30A02 G E022A IRDFP A 15	C	MINISTRY OF INTERNATIONAL TRADE ---- TOKYO 100, JAPAN ---- ----	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- TOKYO 105, JAPAN ---- ----	---- ---- ----	Y P RD U	4,096 ---- COMPRISES VISIBLE AND NEAR INFRARED RADIOMETER	----	----	----	----	----	JAK/AUG-SEP 88/029 09/01/88 E001A 02/01/92 JA
14010 30A02 G E056A IRDFP A 29	B	MITSUBISHI ELECTR CORPORATION (MELCO) ---- MITSUBISHI DENKI BLDG., 2-3 MARUNOUCHI 2-CHROME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	TECHNICAL R&D INSTITUTE ---- ?, JAPAN ---- ----	---- ---- ----	Y P RD U	---- FLIR	----	----	03-05 ---- FLIR	----	----	JAX/ NO. 917/05 05/22/89 E024A / / JA
14010 30A02 G E009A IRDFP A 19	C	NATIONAL SPACE DEVELOPMENT AGENCY ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105 ---- ----	TECHNOLOGY RESEARCH ASSOCIATION OF RESOUCES REMOTE SENSING SYSTEMS ---- ---- ----	REMOTE SENSING TECHNOLOGY CENTER OF JAPAN ---- MINATO-KU, TOKYO 106, JAPAN ---- ----	Y A FP U	02048 ---- BAND 4	014 x 015 ---- PIXEL SIZE	----	0.80 - 01.10 ---- BAND FOUR NEAR-INFRARED BAND 4	----	----	JAA/VOL 3 #13/03 01/13/89 E021A 02/19/87 JA
14010 30A02 G E009A IRDFP A 23	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMTSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	TECHNOLOGY RESEARCH ASSOCIATION OF RESOURCES REMOTE SENSING SYSTEMS ---- ---- ----	REMOTE SENSING TECHNOLOGY CENTER OF JAPAN ---- MINATO-KU, JAPAN ---- ----	N A FP U	2048 ----	14 x 15 ----	----	0.80 - 01.10 ---- BAND 4 NEAR-INFRARED - MESSR	----	----	JAA/VOL 3 #13/03 01/13/89 E021B 02/19/87 JA

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14010 30A02 G E009A IRDFP A 20	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	TECHNONOLGY RESEARCH ASSOCIATION OF RESOURCES REMOTE SENSING SYSTEMS ---- MINATO-KU, TOKYO 106, JAPAN ---- ----	---- ---- ----	N A FP U	02048 ---- BAND THREE -MESSR	14 x 15 ----	----	073 - .080 ---- NEAR INFRARED	----	----	JAA/VOL 3 #13/03 01/13/89 E021B 02/19/87 JA
14010 30A02 G E009A IRDFP A 21	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	TEACHNOLOGY RESEARCH ASSOCIATION OF RESOURCES REMOTE SENSING SYSTEMS ---- ---- ----	REMOTE SENSING TECHNOLOGY CENTER OF JAPAN ---- MINATO-KU, TOKYO 106, JAPAN ---- ----	Y A FP U	2048 ----	----	----	0.5 - 0.7 ---- VISIBLE BAND 1 - VTIR	----	Si-Pin diode ----	JAA/VOL 3 #13/04 01/13/89 E021C 02/19/87 JA
14010 30A02 G E009A IRDFP A 22	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN ---- 2-4-1 HAMAMATSUCHU, MANATO-KU, TOKYO 105, JAPAN ---- ----	TECHNOLOGY RESEARCH ASSOCIATION OF RESOUCES REMOTES SENSING SYSTEMS ---- ---- ----	REMOTE SENSING TECHNOLOGY CENTER OF JAPAN ---- MINATO-KU, TOKYO 106, JAPAN ---- ----	N A FP U	2048 ----	----	----	06.0 - 7.0 ---- LOWEST VALUE FOR BANDS 2,3, AND 4 - VTIR	----	HgCdTe ----	JAA/VOL 3 #13/04 01/13/89 E021D 02/19/87 JA
14010 30A02 G E002A IRDFP A 28	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1 HAMAMATSUCHO, MINATO-KU, TOKYO 105, JAPAN ---- ----	THE MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY (MITI) ---- 1-3-1 KASUMIGASEKI, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	Y P RD U	04096 ---- ERS-1 SATELLITE	----	----	----	----	----	JAK/VOL 7 #27/029 09/01/88 E001B 02/01/92 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 G E009A IRDFP A 45	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- Y. MIYACHI, Y. HORIKAWA & Y.KAMIYA ----	---- ---- ----	---- ---- ----	Y A DT U	02048 ---- MESSR	----	----	0.72 - 1.10 ---- BANDS 3 & 4	----	----	JBT/VOL III/161 1 10/26/8 6 E027A 04/01/8 6 JA
14010 30A02 G E009A IRDFP A 46	C	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- Y. MIYACHI, Y. HORIKAWA, Y. KAMIYA ----	---- ---- ----	---- ---- ----	Y A DT U	02048 ---- MESSER	----	----	0.51 - 0.69 ---- BAND- 1 & 2	----	----	JBT/VOL III/161 1 10/26/8 6 E027B 04/01/8 6 JA
14010 30A02 G E022A IRDFP A 42	C	NEC CORPORATION ---- 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NOBUHIKO MORI & SHUNJI MURAI ---- NOTE - S. MURAI ASSIGNED TO TOKYO UNIVERSITY, YOKOHAMA 226, JAPAN	SUMITOMO METAL MINING CO., LTD ---- 1-3 OHTEMACHI 1-CHOME, CHIYODA-KU,TOKYO 100, JAPAN ---- HIDETOSHI TAKAOKA ----	EARTH RESOURCES SATELLITE DATA ANALYSIS CENTER ---- ?, JAPAN ---- KUNISHIGE TONOIKE & JIRO KOMAI ----	Y A DT U	04096 ---- JERS-1 SATELL ITE NADIR SENSOR	----	----	---- 7 BANDS IMAGES IN THE WAVELE NGTHS OF VISIBL E AND NEARIN FRARED AND SHORT WAVE INFRAR ED	----	----	JAJ/01-26-89/0 69 01/26/8 9 E016A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
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TECHNOLOGY: IR DETECTORS & FOCAL PLANE ARRAYS

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A02 G E022A IRDFP A 43	C	NEC CORPORATION ---- 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NOBUHIKO MORI & SHUNJI MURAI ---- NOTE - S.MORAI IS ON ASSIGNMENT TO THE UNIVERSITY OF TOKYO IN YOKOHAMA 226 JAPAN	SUMITOMO METAL MINING CO., LTD ---- 1-3 OHTEMACHI 1-CHOME, CHIYODA-KU,TOKYO 100, JAPAN ---- HIDETOSHI TAKAOKA ----	EARTH RESOURCES DATA ANALYSIS CENTER ---- ?, JAPAN ---- KUNISHIGE TONOIKE & JIRO KOMAI ----	Y A DT U	04096 ---- JERS-1 SATELL ITE-FO RWARD LOOKIN G SENSOR	----	----	---- 1 BAND IN SHORTW AVE INFRAR ED WAVELE NGTH	----	----	JAJ/01- 26-89/0 69 01/26/8 9 E016B / / JA
14010 30A02 G E022A IRDFP A 44	C	NEC CORPORATION ---- 33-1 SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- NOBUHIKO MORI & SHUNJI MURAI ---- NOTE - S. MURAI ASSIGNED TO TOKYO UNIVERSITY, YOKOHAMA 226, JAPAN	SUMITOMO METAL MINING CO., LTD ---- 1-3, OHTEMACHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- HIDETOSHI TAKAOKA ----	EARTH RESOURCES DATA ANALYSIS CENTER ---- ?, JAPAN ---- KUNISHIGE TONOIKE & JIRO KOMAI ----	Y A DT U	04096 ---- JERS-1 SATELL ITE-NA DIR IMAGE CENTER	----	----	---- VISIBL E REGION WAVELE NGTH .	----	----	JAJ/01- 26-89/0 69 01/26/8 9 E016C / / JA
14010 30A02 G E022A IRCFP A 25	C	UINKNOWN ---- UNKNOWN ---- UNKNOWN ---- ADVANCED EARTH OBSERVATION SATELLITE	---- ---- ----	---- ---- ----	Y P RD U	---- ADVANC ED rVISIB LE AND NEAR-I NFRARE D RADIOM ETER	----	----	----	----	----	JAA/VOL 3 #13/09 01/13/8 9 E023A 01/01/9 3 JA

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** *************** SUB-TECHNOLOGY: IR DETECTOR - CRYOGENIC COOLERS

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
14010 30A04 A E009D IRDFP A 83	E	FUJITSU LTD. ---- 1015, KAMIKODANAKA, NAKAHARA-KU, KAWASKI 211, JAPAN ---- T.YAMASHITA, K. ISHIZAKA & T. UCHIYAMA ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	RADIAT ION COOLER ----	----	JDG/VOL 25 #1/010 03/15/8 9 E051B / / JA
14010 30A04 A E009D IRDFP A 47	E	NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN, (NASDA) ---- 2-4-1, HAMAMATSU-CHO, MINATO-KU, TOKYO 105, JAPAN ---- Y. MIYACHI, Y. HORIKAWA, & Y. KAMIYA ----	---- ---- ----	---- ---- ----	Y A DT U	---- MOS-1 VTIR SENSOR	----	----	----	PASSIV E RADIAT ORS ----	----	JBT/VOL 111/161 1 10/26/8 6 E027C 04/01/8 6 JA

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1 E0000 IR DETECTORS & FOCAL PLANE ARRAYS

This technology category is comprised of two families of sensors that overlap. Sensors are devices that gather energy and convert it to a signal that provides information, while detectors are devices that provide an electrical output that provides a useful measure of incident radiation. Thus, an IR detector is a particular type of sensor.

IR Detectors

Sensors may be classified in many ways. Two common means of classification are by spectral response and by physical configuration. The classification of IR Detectors would contain all types and configurations of sensors that are sensitive to the infrared (IR) portion of the spectrum (0.75 to 30.0 micrometers), and it would include vacuum tube devices, thermocouples, and other physical configurations, as well as solid state devices - and might even be stretched to include linear arrays and two dimensional (or focal plane) arrays. Each of these physical configurations (with the exception of the arrays) are single cell sensors in which the radiation from a target (or subject) is collected by optical means and focused on the entire active surface of the cell.

In some system designs the sensitive surface of the IR detector cell may be focused to a tiny spot, at the target range, and may be mechanically scanned in both the X and Y axis to collect a stream of spectral data that can be used to construct an image of the target.

In contrast, sensor arrays may be either linear (also called pushbroom) arrays which consist of a number of sensors assembled adjacent to one-another, or focal plane arrays (also called frame sensors) which consist of an X-Y matrix of sensors, arranged like the tiles on a floor. While the linear array must be mechanically scanned in the second direction to produce a target image, the focal plane array requires no scanning; it can produce an image by just staring at the target, and thus is sometimes referred to as a "staring array".

We will investigate the full range of physical configurations (up to and including the the focal plane array) under the category of IR detectors, if they are sensitive to the infrared (near or far infrared) portion of the spectrum.

Focal Plane Arrays

The focal plane array is a physical configuration of sensor that contains multiple individual detectors mounted in an X-Y matrix that permits it to provide a complete target image without any mechanical scanning. While the term is usually reserved to describe an electro-optical sensor, they can be designed to be sensitive to any part of that portion of the spectrum, including far infrared (3-15uM), near infrared (.75-3uM), visible (0.4-0.75uM) and ultra-violet (0.01-0.4uM).

Applications

Most of these detectors and/or sensors have a broad scope of applications ranging from commercial/industrial temperature

sensors or photographic and video sensors, to military use in night vision devices, target sensors or trackers in smart weapons, and spacecraft applications as scientific sensors, guidance sensors and imaging sensors for earths resources and intelligence reconnaissance.

Two figures are useful in understanding the selection and application of IR detectors & focal plane arrays. Figure 1 displays the wavelengths and relative intensities for a variety of targets and the atmospheric windows at sea level, while Figure 2 presents the materials and technolgies used in focal plane arrays for each wavelength and their cooling requirements.

These figures provide very important insights into the selection and application of the whole spectrum of IR detectors. From Figure 1 we can see that targets with surface temperatures that are high compared to the environment, such as a furnace, the hot barrel of an artillery weapon, jet airplane exhaust, or even a cigarette, are detectable with sensors in the visible and near infrared region (which require little or no refrigeration). Targets of moderate-temperature observables, such as tanks, trucks, locomotives and conventional aircraft are detectable with mid-range IR sensors that require moderate refrigeration. Targets with relatively low thermal signatures, such as man, factory buildings, and steam ships require sensors in the far-infrared region which demand extreme levels of refrigeration.

The "windows" identified in Figure 1 are portions of the spectrum in which the IR radiation from targets is "not" seriously attenuated by the atmosphere and thus is available for detection at a considerable distance from the targets.

Also, the Silicon (Si) and Gallium Arsenide (GaAs) (intrinsic) detectors are more applicable to the ultra-voilet regions while the extrinsic hybrid detectors have greater application to the IR regions. Some IR focal plane arrays incorporate charge coupled devices (CCD)

84 EC51C Marine Observation Satellite (MOS-1)

In MOS-1, three types of imaging radiometers are installed: a visible and thermal inflared radiometer (VTIR) which takes pictures of the ocean, and clouds in one visible and three thermal infared bands and measures the temperature of the ocean or cloud tops; a multispectral electronic selfscanning radiometer (MESSR) for visible and near infrared bands forcartography; and a microwave scanning radiometer (MSR) for measuring sea surface temperature when it is cloudy.

Visible and Thermal Infrared Radiometer (VTIR)
The VTIR installed in MOS-1 has one visible band (wavelength = 0.5 0.7um) and three thermal infrared bands (wavelength = 6.0-7.0 um, 10.5-11.5 um, and 11.5-12.5 um). Images of clouds, water vapor and the temperature on the sea surface or cloud tops are obtained using this sensor.

The VTIR uses a rotating mirror scanner, a Ritchey-Chretien telescope (a reflecting optical system), radiatively cooled mercury cadmium tellununl (HgCdTe) infrared detectors, and silicon PIN diode.Theinstantaneous field of view (IFOV) on the earth is 900 m for the visible band and 2700m for infrared bands, and the scan width is about 1500km.

The scanning radiometer consists of a scan mirror, its driving motor, a black-body raditor for reference, focusing mirror, filters, relay lenses and detectors mounted on the radiation cooler.

Infrared radiation from the target is conducted to the cooled mercury cadmium tellunum (HgCdTe) detector. Visible light is directly conducted to a silicon PIN diode from the focusing mirror.

Radiation cooler (RC) has the function to cool down the detector temperature by thermal energy radiation into space. The RC temperature is balanced, when the energy input to the detectors is equal to the thermal energy radiated from them. Detectors are then cooled to an ultralow temperature (about 115 K) for operation.

Infrared detectors are mounted on the RC, which is cooled to about 115K. The VTIR's RC has two stages: the stage-1 temperature is about 150K, and that for stage-2 is about 115 K.

The sensor observes the earth when the mirror faces in that direction and calibrates to the reference black-body when the mirror faces it.

Electrical signals from the detectors are amplified, converted to digital, and multiplexed for transmission.

85 E051D Marine Observation Satellite (MOS-1)

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The sensor observes the earth when the mirror faces in that direction and calibrates to the reference blackbody when the mirror faces it.

Electrical signals from the detectors are amplified, converted to digital, and multiplexed for transmission.

86 E052A FUJITSU HAS MANUFACTURED LOTS OF MATERIALS BEING USED INVARIOUS FIELDS; THAT IS AIR-BORNE COMPUTER, TANK, MISSLE,AND BATTLEFIELD SURVEILLANCE FLIR (FORWARD LOOKINGINFRARED DETECTOR).

122 E064A Fujitsu already manufactured an infrared sensor about 1972, and it is proud of being at the top in the industry in the development of the element whose sensitivity is best at normal temperature.

There are two methods employed in the target chasing of a missle: radiowave homing and infrared homing. Infrared homing has characteristics such as the following: 1) Target searching time is short; 2) target identification capacity is high (the temperature of military aircraft, warhips, tanks, etc., is generally high, therefore, high-constant images can be obtained by utilizing infrared rays); 3) different from radiowave, it is difficult for the enemy to disturb.

113 E058L Future Trends:

It is vital that, while putting these capabilities to use, we go on promoting enhancement of functions and special qualities, the search for physical operations, and development of new materials and manufacturing technology. If, based on the current status of the CCD sensors reported in chapters two and three, I presented the tasks that are anticipated from future R&D, they would probably come out like the following.
(1) Development up to now has been based on thinking that gives priority to the physical properties of materials: the idea of "making sensors by making the best use of the inherent qualities possessed by the material." Recently, contrary to the idea described above, thinking that gives priority to specifications has begun to sprout: the idea of "We want to make this kind of sensor. What kind of material should we use, and how should we design it in order to do that?" In order to realize this kind of idea and go on anticipating new structures and functions, it will be necessary to develop a two-dimensional or three-dimensional method of numerical analysis that will accurately simulate optical devices (optical device CAD). (2) Recently research has begun which tries to use for optical sensors such new materials as organic high polymers that possess photochemical reactions (azobenzene, spiropyrane etc.), biopolymers that

possess a photoelectric conversion function (bacterio-rhodopsin etc.). Organic materials have problems: on the point of time, their response is still slow, they lack stability for repeated use, and so on, but they have the advantage of being light, and hence suited to an increase in area, so it is predicted that they will develop into attractive materials. (3) The latest research on OEIC is on a trend which points to optical communications and optical computers. In order to go on applying them to tbese fields, it will be necessary to go on attempting to expand the scale of integration, enhance photosensitivity, develop super high-speed, and so on. Moreover, though I did not mention it in this article, in order to go on developing optical computers and so on, research on optical modulation elements and optical logic elements will begin to be important in addition to development of the kind of performance and materials mentioned above. (4) In regard to image sensors, enhancement of sensitivity, development of higher resolution and development of functions will probably become the nucleus of future development. In order to do this, it will be necessary to develop hyperfine-processing technology that includes a method of picture-element separation, a method of low-noise signal-detection, and proposals for new device composition and structure that will do away with the status quo. The future of three-dimensional image sensor that was proposed as one plan for this new device structure attract attention as a method that realizes increased density and development of intelligence simultaneously. When we look back on the trends that have been described above, we can anticipate that optical sensors will become more and more important as we enter the age of optical information processing which is about to arrive, and that it will go on developing into a key device that will support the society of the

118 E061A FULL-SCALE FABRICATION OF FLIR FOR FIGHTER AIRCRAFT

The Defense Agency's Technical R&D Institute (TRDI) will shortly place an order for the second-phase prototype fabrication of a forward looking infrared radar (FLIR) with Mitsubishi Electcic Corp. As the first phase fabrication ordered in FY 1988 was limited to designing and partial fabrication, TRDI will start full-scale fabrication in the second phase.

TRDI-designed FLIR is aimed at improving perfomance of a fire control system of fighter aircraft. As the FLIR is expected to be developed with Japan's indigenous technology, TRDI itself is not certain how well it would work.

So, TRDI has not decided yet to install it in the FS-X next support fighter of which development is expected to be commenced soon. However, as TRDI plans to spare enough room to accommodate it in the FS-X, the FLIR may be installed later if it turns out to be a good one.

65 E033C GMS-3 is a spin-stabilized geostationary meteorological satellite with mechanical despun antennas. GMSS-3 will be the GMS-2 protoflight spacecraft refurbished to provide more capability and modified to improve its reliability. Hence, the configuration and characteristics of the spacecraft are improved over those of the predecessor, GMS-2 and most subsystems are night-proven.

Overall size, weight and shape of the spacecraft are designed to be compatible with N-II launch vehicles. The spacecraft length is 444 cm at launch and 345 cm on station, and the diameter is 215 cm. The weight when GMS-3 is separated from N-II third stage is approximately 681 kg, and the spacecraft dry weight on station is approximately 287 kg.

The spinning section includes VISSR and supporting subsystems. The forward assembly consists of VISSR, magnesium thrust tube, honeycomb equipment shelf, electronics, batteries, main wire harness, Reaction Control Subsystem (RCS) tanks and thrusters, solar panel, and thermal barriers. The aft assembly includes an Apogee Kick Motor (AKM), wire harness, AKM adapter, and separation hardware. The aft assembly is jettisoned after motor burnout.

The satellite mission life is 4--5 years due to thelimited amount of on-board hydrazine fuel; however, thedesign life is 5 years. Redundancy of mission-criticalfunctionsis provided to ensure electronics lifetimessignificantly in excess of 5 years. The solar panel powerof 263 W includes an approximately 16W margin at the endof 5 years (summer solstice)

VISSR

The Visible and Infrared Spin Scan Radiometer (VISSR) isused to obtain visible and infrared spectrum mappings ofthe earth and its cloud cover with specially designedoptical telescopes and detector system. A complete 20 x20 degree scan of the full earth disk can be accomplishedevery 30 minutes utilizing the spacecrafts 100 rpm spinmotion for east-west scans. Primary scanning requires 25minutes, mirror retrace 2.5 minutes, and spacecraftstabilization another 2.5 minutes.

Using its scan, primary, and secondary mirrors, theoptical telescope collects visible and infrared energyfrom images of the earth's surface and brings theseimages into focus at the focal plane. Visible fiberoptics and infrared relay optics reley images from thetelescope focal plane to redundant visible and infrareddetectors. Photomultiplier Tubes (PMT) detectors convertvisible light into visible analog signals, and HgCdTedetectors, cooled by a radiation cooler, converts theearth's radiation into infrared analog signal. The VISSRoutputs are feed to VISSR Digital Multiplexer (VDM)unit., which is internally redundant, for processing.

VISSR CHARACTERISTICS

Function --- Provide Visible & Infrared spectrum mappingof earth & cloud cover

	Visible Channels	Infrared Channels
Field Of View	35 x 31 urad	140 x 140 urad
Band	0.50 to 0.75u	10.5 to 12.5 u
Resolution	1.25km	5.0 km
Scanning Lines	2500 x 4	2500
Scan Step repeat	+-1.8urad	+-1.8 urad
Noise Performance	S/N>=45 alb=100%	NE T<+0.5K 300K
	S/N>=6.5 alb=2.5%	NE T<+1.5K 220K

100 E057C PREPARATIONS FOR GMS-5. DESIGN AND DEVELOPMENT OF THE GMS-5 SPACECRAFT IS UNDERWAY. LAUNCH ON A NASDA H-II ROCKET IS SCHEDULED FOR 1993- 1994. AS WITH PREVIOUS GMS SATELLITES, GMS-5 WILL BE SPIN STABILIZED.

NEW GMS-5 PAYLOADS. VISSR WAVELENGTHS WILL CHANGE ON-GMS-5 TO 0.55-0.90 MICROMETERS IN THE VISIBLE, WILL INCLUDE A "SPLIT WINDOW" INFRARED RANGE OF 10.5- 11.5 AND 11.5- 12.5 MICROMETERS, AND WILL HAVE A THIRD 6.5-7.0 MICROMETER INFRARED WATER VAPOR CHANNEL. NASDA CONFIRMED THAT THE SEM WILL BE DROPPED FROM THE GMS-5 PAYLOAD DUE TO BUDGETARY CONSTRAINTS AND ITS RELATIVELY SMALL JAPANESE USER COMMUNITY. A SEM WILL AGAIN BE FLOWN ON NASDA'S ENGINEERING TEST SATELLITE NUMMBER SIX (ETS-6) SCHEDULED FOR LAUNCH IN 1992. NASDA ALSO CONFIRMED THAT THE MARITIME SAFETY AGENCY (MINISTRY OF TRANSPORT) WILL CONDUCT A GEOSTATIONARY SEARCH AND RESCUE (SAR) EXPERIMENT--SIMILAR TO THE ONE, ON THE U.S.NOAA/NESDIS GOES SATELLITE--USING THE GMS-5 ONBOARD COMMUNICATIONS SUB-SYSTEM THAT RECEIVES AND RETRANSMITS DCP SIGNALS. GMS-5 WILL BE LAUNCHED JOINTLY WITH THE SPACE FLYER UNIT SATELLITE (SFU), AN EXPERIMENTAL MICROGRAVITY MISSION SPONSORED BY NASDA, THE MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY (MITI), AND THE INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE

98 E057A ON OCTOBER 6, 1989, NOAA SCIOFF MET WITH OFFICIALS OFJAPAN'S NATIONAL SPACE DEVELOPMENT AGENCY (NASDA) TOLEARN THE STATUS OF THE JAPANESE-GEOSTATIONARY METEOROLOGICAL SATELLITE(GMS) PROGRAM. SINCE 1977 A TOTALOF THREE GMS SATELLITES, IN SEQUENCE, HAVE PROVIDEDMETEOROLOGICAL AND ENVIRONMENTAL DATA SERVICES TO USERS IN JAPAN AND OTHER COUNTRIES THROUGHOUT ASIA .
GMS PROGRAM MISSIONS. FROM A GEOSTATIONARY VANTAGE POINT APPROXIMATELY 36,000 KILOMETERS ABOVE THE EARTH'S EQUATOR, GMS SATELLITES PERFORM FOUR BASIC MISSIONS.FIRST, THE SATELLITES OBSERVE THE EARTH'S ATMOSPHERE ANDSURFACE USING THE VISIBLE AND INFRARED'SPIN SCANRADIOMETER (VISSR). VISSR IMAGERY PROVIDES INFORMATION
ON CLOUD COVER; WIND SPEED AND DIRECTION; AND GROUND, SEASURFACE AND ATMOSPHERIC TEMPERATURES. THE INFORMATION HASMANY METEOROLOGICAL AND ENVIRONMENTAL APPLICATIONS WHICH BENEFIT A WORLDWIDE USER COMMUNITY. SECONDLY, THE
SATELLITES DIRECTLY BROADCAST AND DISSEMINATE GROUND PROCESSED VISSR IMAGERY (BOTH DIGITAL AND ANALOG) TO USERSTATIONS. THIRD, THEY COLLECT AND RETRANSMITMETEOROLOGICAL AND ENVIRONMENTAL DATA FROM DATACOLLECTION PLATFORMS (DCP) ON SHIPS, BUOYS, AIRCRAFT ANDAT REMOTE LAND LOCATIONS. FINALLY, THE SATELLITES MEASUREFLUX OF SOLAR PROTONS, ALPHA PARTICLES AND ELECTRONS AT THE SPACECRAFT USING THE ONBOARD SPACE ENVIRONMENTMONITOR (SEM).

99 E057B LATE NOVEMBER-EARLY DECEMBER OF THIS YEAR GMS-3 WILL RELINQUISH ITS POSITION TO THE APPROACHING GMS-4 AND BEGIN ITS MOVE WEST TO A STANDBY STATION AT 120 DEGREES EAST LONG. GMS-4 WILL ASSUME THE OPERATIONAL 140 DEGREESEAST LONG POSTION BY EARLY DECEMBER. GMS-3 OPERATIONS AT 120 DEGREES EAST LONG WILL BE ABLE TO MONITOR WEATHER FRONTS MOVING EAST OVER THE ASIAN MAINLAND AND PROVIDE BETTER COVERAGE OF DEVELOPING MONSOON CONDITIONS. DATA WILL BE DISSEMINATED THROUGH ESTABLISHED WORLDMETEOROLOGICAL ORGANIZATION (WMO) NETWORKS AND UTILIZED BY NATIONS OF THE REGION.

GMS-4 CHANGES. GMS-4, A MODIFIED VERSION OF THE CMS-3B BACKUP SPACECRAFT, WAS LAUNCHED ON SEPTEMBER 6, 1989, BYA NASDA H-I ROCKET. DEVELOPMENT COSTS OF CMS-4 WERESHARED AMONG NASDA AND JMA IN THE SAME PROPORTIONS AS FORGMS-3. SIGNIFICANT CHANGES IN THE GMS-4 SPACECRAFT ARE:
A) THE INCLUSION OF DOMESTICALLY DEVELOPED USBTRANSMITTER-RECEIVERS AND HIGH FREQUENCY SECTIONS OF THE S-BAND TRANSMITTERS AND DRIVER AMPLIFIERS,B)THE SUBSTITUTION OF LED ENCODERS FOR CONVENTIONAL ENCODERBULBS IN THE VISSR IMAGER, C) AN IMPROVED INFRARED

CALIBRATION CAPABILITY, D) THE COATING OF THE SPACECRAFT'S OUTER SURFACE TO PREVENT ELECTROSTATIC DISCHARGE, AND E) THE ADDITION OF EXTRA STATIONKEEPING HYDRAZINE PROPELLANT FUEL TO SUPPORT THE SATELLITE'S FIVE YEAR DESIGN LIFE. NASDA STATED THAT VISSR IMAGERLUBRICANT PROBLEMS EXPERIENCED BY GMS-3 ARE EXPECTED TO BE ALLEVIATED BY THE INCREASE BY 1.5 TIMES OF THE SCANNING MIRROR/DRIVE MOTOR POWER.

GMS-4 CHECKOUT. GMS-4 CURRENTLY IS STATIONED AT 160 DEGREES EAST LONG IN ITS "GEOSTATIONARY ORBIT SUBPHASE" OF POST-LAUNCH CHECKOUT. ATTITUDE CONTROL ANDCOMMUNICATIONS SYSTEMS ARE NOW BEING TESTED, AND IMAGING SYSTEM TESTS OF ONE MONTH'S DURATION ARE SCHEDULED TO BEGIN OCTOBER 16. PLANS ARE BEING MADE FOR ITS FINAL WESTWARD MANEUVER TO 140 DEGREES EAST LONG, ANDOPERATIONAL COVERAGE IS EXPECTED TO BEGIN ALMOSTIMMEDIATELY UPON ARRIVAL IN EARLY DECEMBER. GMS-4 WILL
CLOSE ♥ E056D

101 E057D PLANNING FOR GMS-6 . JMA, THE MARITIME SAFETY AGENCY, AND THE CIVIL AVIATION BUREAU--ALL WITHIN THE MINISTRY OF TRANSPORT--ARE CONSIDERING A COMBINED METEOROLOGICAL/COMMUNICATIONS/SEARCH AND RESCUE MISSION FOR THE NEXT-GENERATION GMS-6 SPACECRAFT. THE POTENTIAL COMMUNICATIONS/SEARCH AND RESCUE COMPONENT WOULD SERVE AN ENVISIONED NATIONAL AVIATION, MARITIME AND LAND TRANSPORT NAVIGATION/TRAFFIC CONTROL/TELECOMMUNICATIONS SYSTEM. NASDA STATED THAT SUCH A COMBINED MISSION WOULD REQUIRE A LARGER "MULTIMISSION" SPACECRAFT, AND THAT THE THREE-AXIS STABILIZED ETS-6 SATELLITE IS SEEN AS A POTENTIAL BUS. THEY WERE QUICK TO MENTION THAT THIS HAS YET TO BE DECIDED, AND THAT A "TRADE OFF STUDY" COULD BE DONE IN WHICH SPIN-STABILIZED TECHNOLOGY WOULD BE CONSIDERED AS ANOTHER OPTION. NASDA ALSO SAID THAT IF A THREE-AXIS STABILIZED BUS WERE CHOSEN, IT WOULD REQUIRE A U.S. "GOES-NEXT TYPE IMAGER" (AS THERE CURRENTLY IS NO THREE-AXIS COMPATIBLE VISSR IMAGER). THE FUTURE GMS-6 IS TENTATIVELY SCHEDULED FOR LAUNCH IN 1998. NASDA SAID A "PRE-PHASE A" STUDY WOULD BEGIN THIS YEAR, WITH A PHASE A STUDY SOON TO FOLLOW.

59 E067A NASDA Orders 2 BBM Sensors for ADEOS

The National Space Development Agency of Japan (NASDA) issued an order for an advanced visible near-infraredradiometer (AVNIR) to Mitsubishi Electric Corp. andanother for an ocean color temperature scanningradiometer(OCTS) to NEC Corp.: both sens ors will becarried by the earth observation platform technology satellite (ADEOS). The orders were actually for the testmodels(BBM) of the sensors. However, because only onecompany was selected as the vendor for each model, ithas become certain that these companies will be the manufacturers of the sensors which will be actuallycarricd by the satellite.

68 E043A Japan's first Earth observation satellite, MOS-1, isabout to be launched, and the follow-on, ERS-1, is nowunder development. Moreover, the future earth observationprogram, including participation in the Polar Platform Program which is now under study within NOAA, NASA, ESA,is also studied in Japan.

The main mission objectives are as follows:

1) to establish the technologies of Earth observationfrom space by the Synthetic Aperture Radar and OpticalSensors.
2) to explore non-renewable resources and to monitor landuse, agriculture, forestry, fishery, environmentalprotection, prevention of natural disasters, surveillanceod coastal regions, ect.

BASIC VISIBLE INFRARED RADIOMETER SPECIFICATIONS

WAVELENGTH	TO BE DETERMINED
POLARIZATION	-
BAND NUMBER	4
SPATIAL RESOLUTION	18m
OFF NADIR ANGLE	-
SWATH WIDTH	75Km
STEREOSCOPIC IMAGING	YES

69 E043B Japan's first Earth observation satellite, MOS-1, isabout to be launched, and the follow-on, ERS-1, is nowunder development. Moreover, the future earth observationprogram, including participation in the Polar Platform
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BASIC SHORT WAVELENGTH INFRARED RADIOMETER SPECIFICATIONS

WAVELENGTH	TO BE DETERMINED
POLARIZATION	-
BAND NUMBER	3 TO 4
SPATIAL RESOLUTION	18m
OFF NADIR ANGLE	-
SWATH WIDTH	75Km
STEREOSCOPIC IMAGING	-

74 E046A The Japan Defense Agency (JDA), Kawasaki HeavyIndustries, and NEC will begin development of the (Shin-
Jyu-Mat) antitank missile in fiscal year 1990 to replacethe Type 79 antitank missile known as the Jyu-MAT orKAM9. JDA plans to produce a prototype using exclusively
domestic technologies by 1993. An infrared sensor locatedin the missile head will acquire the target and transmitinfrared images to the operator, who will guide themissile to the target using a TV screen. NEC will developthe 8- to 80-micmon infrared sensor, while Kawasaki HeavyIndustries will be in charge of overall development.

97 E056D Infrared FLIR Development

The Defense Agency, Mitsubishi Electric Co. [MELCO] and Fuitsu have begun reseach fabrication of a forward-looking surveillance device that uses an infrared sensor (FLIR) to be mounted on fighter aircraft. It is characterized by the dual functions of surface surveillance and air to air surveillance and, taking advantage of the Japanese specialties of semiconductors and graphic processing technology, will be the world's most advanced system. If the trial fabrication is successful, development will be hurried along and the

device will be mounted in the next fighter support aircraft (FSX) and the future fighter attack aircraft. Along with MELCO and Fujitsu, both NEC and Toshiba have advanced technology in the field of infrared sensors. These four companies submitted independent proposals for the FLIR research fabrication, competing for acceptance, but in the end MELCO and Fujitsu were chosen as prime contractor and cooperating contractor respectively, and were able to start research. They intend to build a working version in about three years, then shift to the development stage.

73 E045A JAPAN: MISSLE DEVELOPMENT

TRDI begun a four-year program in fiscal year 1988 todevelop the XASM-2 for deployment with the Air Self-Defense Force in 1991. The missile will be the follow-onto the ASM- 1 for Japan's next-generation fighter air-craft, the FSX. The XASM-2 will have identificationfriend-or-foe (IFF) recognition and targetingcapabilities enhanced by electronic counter-counter measures (ECCM), infrared counter-counter measures (IRCCM), high perforation power, and stand-offcapabilities. To ensure good ECCM, targeting, and kill capabilities, the design will include a low-observable main wing, an infrared imaging guidance system, a positioning system, a high-density-fuelturbojet propulsion system, and powerful plastic-bonded explosives. The missile will acquire the infraredsignature of an enemy vessel through imaging sensors and attack only when the image matches that storedin the system's memory. MHI is the contractor for theoverall system, with Fujitsu responsible for theguidance system. The DA appropriated 6 billion yenfor XASM-2 development in fiscal year 1988 and plans to
request a similar amount for 1989.

Since 1986 TRDI has been working on development of the XAAM-3 missile, to replace the AIM-9L Sidewinder, withMHI as the prime contractor. The missile, to be deployedwith the Air Self-Defense Force sometime after 1990,will give an aircraft greater lateral attack capabilityand will have infrared homing and IRCCM features.

The TRDI also plans to develop the XSSM-2 ship-to-ship missile for deployment with the Maritime Self-Defense Force in 1990. The missile will be modeled after the SSM-1 and will be equipped with the SSM-1 propulsionsystem, providing high performance at low production cost.

75 E047A The University of Tokyo's Research Center for Advanced Science and Technology has produced a prototype infrared sensor using silicon carbide fiber. The sensor does notrequire lead wires since the detection device is made offibers which function as both device and lead. The 15-
micron-diameter fiber has a limited heat capacity sothat the temperature rises quickly with only slightexposure to infrared radiation. Response rate hasreached 30 milliseconds and is expected to increase to 10 milliseconds. The group has formed a joint venture
with Nippon Carbon and Sogo Keibi Hosho Company tocomplete development.

96 E056C Infrared FLIR Development

The Defense Agency, Mitsubishi Electric Co. [MELCO] and Fuitsu have begun reseach fabrication of a forward-looking surveillance device that uses an infrared sensor (FLIR) to be mounted on fighter aircraft. It is characterized by the dual functions of surface sur-

veillance and air to air surveillance and, taking advantage of the Japanese specialties of semiconductors and graphic processing technology, will be the world's most advanced system. If the trial fabrication is successful, development will be hurried along and the device will be mounted in the next fighter support aircraft (FSX) and the future fighter attack aircraft. Along with MELCO and Fujitsu, both NEC and Toshiba have advanced technology in the field of infrared sensors. These four companies submitted independent proposals for the FLIR research fabrication, competing for acceptance, but in the end MELCO and Fujitsu were chosen as prime contractor and cooperating contractor respectively, and were able to start research. They intend to build a working version in about three years, then shift to the development stage.

93 E055A New Infrared Sensor Developed

Professor H. Yanagida, et al. at the Center forLeading-edge Science and Technology Reseach of The University of Tokyo developed a new type of highly sensitive infrared sensor using a metal reinforcer,silicon carbide fibers, as the detection element incollaboration with Nippon Carbon Co, Ltd and Sogo KeibiHosho Co, Ltd (T. Murai, president).

The response speed of the new sensor is 10 milliseconds, four times as fast as conventional infrared sensors, and will be very useful as anti-crime sensors for buildings, etc. In addition, if the response speed can be further increased to 1 millisecond, it can be used for the detection of speeding violations (mousetrap) on highways. For the time being, this sensor will be advanced for commercialization as an anti-crime alarm system; Nippon Carbonwill be responsible for manufacturing the products, and Sogo Keibi Hosho is planning to market it as early as next year.

The silicon carbide fibers used for the new sensor are fine fibers of 15 microns (1 micron is 1 /1000 mm)in diameter. Because of its high tensile and heat strengths, it is widely used as a structural material for metal reinforcement. However, it has not been used previously as anelectrically functional material.
Professor Yanagida, et.al. took note of the propety of silicon carbide fibers to undergo sensitive changes in electrical resistance resulting from slight temperature changes caused by infrared rays. They deviced an entirelynew application for silicon carbide fibers by applyingthe above property to make infrared sensors.

Although the newly developed sensor can be usedimmediately for practical anti-crime applications inbuildings, the goal of Professor Yanagida, et al. is todevelop new applicalions by increasing the response speedof the sensor to 1 millisecond. Specifically, theapplication is for a new speeding violation detectionsensor. Currently, violators are detected with soundwaves or a laser, in which case, however, the "mousetrap"can be discovered by drivers having counter detectionsystems mounted in their automobiles. However, sensorsusing infrared rays cannot be counter-detected and willbecome a powerful weapon for catching speeders.

77 E049A GEOSTATIONARY METEOROLOGICAL SATELLITE-4 (GMS-4)

* METEORLOGICAL SATELLITE SERVICES AS PART OF A NETWORK OF METERORLOGICAL SATELLITES FOR THE WORLD WEATHER WATCH (WWW) PROGRAM

* WEATHER WATCHED BY VISSR

* COLLECTION & DISTRIBUTION OF WEATHER DATA

* MONITORING OF SOLAR PARTICLES

* MISSION LIFE: 5 YEARS

* ORBIT: 140 DEG E (GEO)

* LAUNCH DATE: AUG 88

* VEHICLE: H-I 4

* OPERATOR OF SATELLITE: NASDA UNDER CONSIGNMENT OF JMA

* USER: JAPAN METEORLOGICAL AGENCY (JMA)

* PRIME CONTRACTOR: NEC

* SUBCONTRACTOR: HUGHS AIRCRAFT COMPANY

78 E049B MARINE OBSERVATION SATELLITE-1 (MOS-1A & MOS-1B)

* OBSERVATION OF MARINE PHENOMENA AND ESTABLISHMENT OF FUNDAMENTAL TECHNOLOGIES FOR EARTH OBSERVATION SATELLITES

* MISSION EQUIPMENT: MESSR (MULTI-SPECTRUM ELECTRONIC SELF-SCANNING RADIOMETER), VTIR (VISIBLE & THERMAL INFRARED RADIOMETER), MSR (MICROWAVE SCANNING RADIOMETER)

* MISSION LIFE: 2 YEARS

* ORBIT: SUN-SYNCHRONOUS (ALTI:900km, INC:99 DEG.)

* LAUCH DATE: WINTER 87 & 1990

* VEHICLE: N-II-8 AND H-I

* OPERATOR OF SATELLITE: NASDA

* USERS: MULTI-USER

* PRIME CONTRACTOR: NEC

79 E049C

80 E049D ADEOS - ADVANCED EARTH OBSERVING SATELLITE

MISSION - * CONTINUITY & ADVANCMENT OF JAPANESE EARTH OBSERVATION TECHNOLOGIES.
* CONTRIBUTION TO INTERNATIONAL COMMUNITIES
* DEVELOPMENT OF ADAVNCED OPTICAL SENSORS
* CONDUCT OF INTER-SATELLITE EARTH OBSERVATION DATA RELEY
* DEVELOPMENT OF A MODULAR & UNIT TYPE SATELLITE

WEIGHT: 3.0 TONS

ATTITUDE CONTROL: THREE AXIS STABILIZED

PAYLOAD: OCTS, AVNIR (ADVANCED VISIBLE & NEAR INFRARED REDOMETER, AO SENSORS

MISSION LIFE: 3 YEARS

ORBIT: SUN-SYNCHRONOUS SUBRECURRENT (ALTI: 800km)

12 E0000 FOCAL PLANE ARRAYS - ULTRAVOILET REGION (UV)

Focal plane arrays with moderate to large quantities of detector elements have been built using CCD technology that are sensitive to radiation in the UV region. Primarily the most sucessful technology is the monolithic intrinsic Si.

13 E000C FOCAL PLANE ARRAYS - VISIBLE REGION - CCD

Focal Plane Arrays based on monolithic intrinsic Si of 10,240x96 elements have been built for the visible and near IR regions of the spectrum.

51 E028B MUSE-A

The ISAS (Institute of Space and Astronautical Science)has started a new project, Muse-A, by the approval of theSpace Activities Commission.

MUSES is an acronym for Space Engineering Spacecraftlaunched by the Mu rocket which is a three stage solidrocket developed by ISAS.

MUSES-A is dedicated to a mission of double lunal swingbywhich is a mandatory technology to be mastered beforeGeotail, a joint US-Japan program for ISTP (InternationalSolar Terrestrial Physics program). Besides the swingby,the MUSES-A spacecraft will carry a tiny satellite at-
acched to the top, and inject it into an orbit around themoon prior to the first lunar swingby.

Japanese planetary scientists regard the mission ofMUSES-A not only as a verification of Technology forGeotail, but also as a precursor for future scientificlunar exploration. Recent study carried out in a plantaryscientist group has brought a concept of a lunar probecarving penatrators and some remote sensing instruments.

119 E062A The optical sensor system (OPS) that will be carried on Earth Resouces Satellite-1 (ERS-1) will be equivalent to a high-performance eye which observes the Earth from space, and will obtain data which will be useful in investigating such resources as oil and minerals. We have now completed the engineering model (EM) that we have been developing as a large project of MITI, and delivered it to the satellite. This OPS obtains high-resolution images and steroscopic images by dividing light of a wide range of wavelengths, from visible to short-wavelength infrared, into multiple bands. For this purpose it employs many new technologies, such as a wide-angle, high-resolution aspherical optical system and a 4,096 element CCD [charge coupled device].

The main features of the OPS are as follows:

I) Observation bands: 3 visible near infrared bands 0.52 to 0.86 micron); 1 stereoscopic vision band (0.76 to 0.86 micron) and wavelengths; 4 short-wavelength infrared bands (1.5 to 2.4 micron)

II. Field of observation: 75km

III. Surface resolving power: 18x24 m

At present we are designing and manufacturing a proto flight model (PFM) of the OPS which can actually be launched, incorporating the of the EM.

66 E034A The MOS- 1 is the first satellite developed by Japan specifically for a remote sensing mission. The MESSR images the surface ofthe earth with four bands of the light spectrum from visual to near infrared (0.5um - 1.1um). The reflected light from the earth's surface is focused into images by the MESSR telescopes with the use of a lens system. Each telescope output light is divided into two bands by prisms and filters, and each light is focused on a detector. This new electronic scanning radiometer using CCD sensors for detectors provides a high resolution through high registration stability, wide wavelength range, and uniform picture quality.

The heart of the MESSR is the photoelectric detector which employs CCD image senors for each band. A CCD image sensor operates as both an imager and/or sequential shift register. The CCD image sensor is a LSI device made up of 2048 light sensitive CCD elements,shift register, and amplifers, all integrsted on one silicon chip and produced in the form of a dual in line package.

When CCD image sensors are used for detection the following benefits are realized :

* The positions of 2048 picture elements on one line are fixed so that the registration accuracy is extremely good.

* Each CCD image sensor section is compact, ensuring ease of wiring.

* No high voltage is required and the power consumption is low.
* One one chip construction solid-state cicuitry, each CCD image sensor provides high reliability.

* Using CCD image sensors, mechanical scanning is not required.

The Messer subsystem developed for Japan's MOS-1 system has been successfully demonstrated and tested. This subsystem currently being manufactured is capable of imaging the earth and transmitting the imagig data to ground stations for processing. The following components make up the MESSR subsytem:

* Scan Radiometer
  This unit employs telescopes and CCD image sensors which converts the object scene on the ground to an image signal.

* Signal Processor Unit
  This unit performs analog-to-digital conversion and modulation of the image signal.

* X- Band Transmitter
This unit, a high speed data tranmitter operates in the X-Band (8GHz band) and provides Watts of RF power to the satellite antenna which is oriented towards the ground.

76 E048A JAPAN: TOSHIBA CCD TECHNOLOGY

Toshiba has made a number of advances in the development of charge-coupled devices (CCDs), components which have important applications in the image processing industy. These devices are expected to lead to improvement ofpicture quality by improving the optical smear-to-signal ratio, a major technical obstacle to industrialapplications, according to July reporting in the Tokyo TOSHIBA REVIEW. One such CCD has a two-thirds-inch format, 400,000 pixels, and a variable electronic shutter function. Ahorizontal resolution of more than 700 rasters isobtained when three of these devices are used in abroadcast camera. To reduce the optical smear-to-signalratio, a frame interline transfer (FIT) structuce isintroduced, so that the effective shutter speed can beadjusted fast enough to freeze the action of moving objects. This high-density-pixel CCD has a sensitivity of58mV/lx and a dynamic range of 75 dB.

Toshiba has also developed a new, high-sensitivity CCD area image-sensing device which brings higher resolutionto VCR camera applications. The one-half inch format CCD has 350,000 pixels and complementary mosaic-on-wafer color filters. The electronic shutter function operatesat a speed of 1/1000 of a second, and because thehorizontal clock frequency selected is a multiple of the VHS standard color recording carrier, it is possible tosimplify the recording circuits. Moreover, the company has developed the technology for forming color filtersdirectly on CCD solid-state imaging sensors.

In the area of linear image sensors, the company hasdeveloped devices with 2048 elements (model TCD-142D) and 2592 elements (TCD-1 43D). A hid-gain on-chipamplifier and improved techniques for isolation ofphotosites result in responsiveness four to six timesgreater than conventional CCDs of the same pixel size.Adoption of a fully depleted photodiode structure has made it possible to suppress a significant amount ofthe dark output voltage, thus increasing the device'ssignal-to-noise ratio by a factor of 10 in comparisonto conventional devices.

In response to recent increasing demand for color systemsin offce automation equipment, the company has developed a contact-type color CCD image sensor that is adaptableto systems requiring high-speed scanning and highresolution. The device is capable of scanning full-sizedocuments using a rod-lens array. The color filters (red,green, blue) in the constituent chips employ monolithiccolor filtering techniques.

In addition, Toshiba has recently developed twocontact-type in-line CCD linear image sensors. The devices provide a resolution of eight dots per millimeter. Clock drivers are integrated on chips andthe maximum input capacitance of the devices is keptbelow 40 pF, so that the devices can be operated by 5-volt timing pulses.

2 E0000 IR DETECTOR - PHOTOCONDUCTOR - PbS

The two principal types of IR detectors are thermal and photon. Thermal detectors were employed in the past in the form of thermocouples (which is a junction of two dissimilar metals that

will generate a voltage that is dependant on the junction temperature) and thermopiles, which are linear arrays of thermocouples. Current and future detector development appears to be concentrated on various forms of photon detectors, in which an absorbed photon of the signal energy will activate an electron, affecting the electrical characteristics of the detector, such as the electrical conductivity of a semiconductor type. While photon detectors have a much faster response then thermal detectors, they often require elaborate means of refrigeration.

Photoconductors

Photoconductive and photodiode detectors are made of semiconductor materials in which most of the electrons are bound in the crystal lattice. Traces of impurities in semiconductors can be used to change the crystal-lattice such that some bonds may be weaker so that electrons are more easily freed (n-type semiconductor) or such that electron acceptors are present and holes are more easily produced (p-type semiconductor). The semiconductors have the trace impurities will respond to a longer wavelength than the pure material, and are known as extrinsic. The pure materials are called intrinsic.

Photodiodes

Photodiode detectors each contain a junction, generally between p- and n-type material in a single crystal. P-I-N diodes include a region of intrinsic between the p and the n, which increases the region with electric field. Schottky barrier photodiodes have a metal-semiconductor interface, where electrons are emitted into the semiconductor when excited by a photon.

PbS, lead sulfide is a very common photoconductor material used in many commercial applications, such as automatic exposure sensors for cameras, particularly because of its operation at ambient temperature.

It should be noted that the detectivity measure (D*) is a function of the wavelength and is related inversely to the operating temperature (maximum detectivity at lowest temperatures).

26 E005A A new field radiometer has been developed to provide ground truth data for the optical sensor of the Japanese ERS-1 (Earth Resources Satellite), which is scheduled to be launched in 1992. This radiometer has two motor-driven filter wheels, each of which can contain up to eight filters and corresponds to the silicon and lead-sulphide detectors respectively. The same field of view exactly is guaranteed to all the spectral bands, because only one aperture is used to observe a target. It takes approximately twenty seconds to perform one continuous measurement for the seven spectral bands equivalent to the ERS-1 sensor. A portable lap-top computer controls the radiometer and records measured results on a floppy disc. An officially-calibrated lamp and a standard reflection plate mounted on an optical bench were also prepared for the purpose of absolute energy calibration of the radiometer. Preliminary investigation has shown that this newly developed radiometer can provide reliable spectral data.

52 E029A AF SERIES PbS DETECTORS

THESE DETECTORS OFFER AN ECONOMICAL CHOICE WITH GOOD

SENSITIVITY IN THE 1 TO 3 MICRON SPECTRAL REGION. A COVER GLASS AND PROPRIETARY BONDING CEMENT PROVIDE SUPERIOR HUMIDITY RESISTANCE AND STABILITY.

53 E029B AP SERIES PbS DETECTORS

THESE DETECTORS OFFER AN ECONOMICAL CHOICE IN THE 1 TO 3 MICRON SPECTRAL REGION. THE PACKAGE PROVIDES AN EXCELLENT MEANS FOR PROVIDING PERFORMANCE IN A HOSTILE ENVIRONMENT WHICH MAY DOWNGRADE THE PERFORMANCE OR LIFE OF AN UNPACKAGED PROTECTOR.

54 E029C AT2 SERIES PbS DETECTORS

AT2 SERIES PbS DETECTORS ARE MOUNTED ONE A TWO STAGE THERMOELECTRIC COOLER AND PACKAGED IN A TO-5 AND A TO-8 CAN. THE DETECTORS OFFER AN ECONOMICAL CHOICE WITH EXTREMELY HIGH SENSITIVITY IN THE 1 TO 3.5um SPECTRAL REGION AND COMPARES WITH DEVICES OPERATING AT 77 DEGREES k WITHOUT THE INCONVIENCE OF LIQUID COOLING TECHNIQUES.

55 E029D PbSe DETECTORS

BT2 PbSe DETECTORS MOUNTED ON TWO STAGE THERMOELECTRICCOOLERS AND PACKAGED IN EITHER TO-5 OR TO-8 CANS. THESEDETECTORS OFFER AN ECONOMICAL CHIOCE WITH EXTREMELY HIGHSENSITIVITY IN THE 1 TO 5 MICRON SPECTRAL REGION ANDCOMPARES WITH DEVICES OPERATING AT 77 DEGREES k WITHOUTTHE INCONVIENCE OF THE LIQUID COOLING.

102 E058A THIS ARTICLE WAS WRITTEN BY THE PERSON INDICATED IN THENAME FIELD. THE ARTICLE CAME FROM THE 1988 JOINTCONVENTION RECORD OF INSTITUTE OF ELECTRONICS ANDINFORMATION ENGINEERS OF JAPAN.

103 E058B THIS ARTICLE WAS WRITTEN BY THE PERSON INDICATED IN THENAME FIELD. THE ARTICLE CAME FROM THE 1988 JOINTCONVENTION RECORD OF INSTITUTE OF ELECTRONICS ANDINFORMATION ENGINEERS OF JAPAN.

124 E066A

125 E066B

3 E0000 IR DETECTOR - PHOTOCONDUCTOR - InSb

InSb, Indium Antimonide detectors are photodiodes generally used in a photovoltaic mode.

(SEE DISCUSSION ON SHEET A)

60 E032A

108 E058G THIS ARTICLE WAS WRITTEN BY THE PERSON INDICATED IN THENAME FIELD. THE ARTICLE CAME FROM THE 1988 JOINTCONVENTION RECORD OF INSTITUTE OF ELECTRONICS ANDINFORMATION ENGINEERS OF JAPAN.

4 E0000 IR DETECTOR - PHOTOCONDUCTOR - HgCdTe

HgCdTe, Mercury cadmium Telluride is probably the most valuable material for sensors in tactical weapons applications for a number of reasons:

a. Its spectral sensitivity can be fine tuned in the broad range of 1 to 14 microns by adjusting the proportions of Hg and Cd.

b. They provide the highest performance of all available IR detectors, with the highest detector operating temperatures, and thus require the least amount of cryogenic cooling.

c. The photovoltaic type detector (which operate at zero bias voltage) can detect IR radiation while dissipating no electrical power at the cooled surface.
(SEE DISCUSSION OF PHOTOCONDUCTORS ON SHEET A)

32 E004B Outline of MOS-1 Verification Program (MVP)

Abstract

Marine Observation Satellite 1 (MOS-1) was successfully launched from
Tanegashima Space Center, NASDA by N-II launch vehicle at 10:23 JST
(1:23 UT) on February 19, 1987. The MOS-1 has 4 mission instruments:
(1) Multi-Spectral Electronic Self Scanning Radiometer(MESSR), (2)
Visible and Thermal Infrared Radiometer(VTIR), (3) Microwave Scanning
Radiometer(MSR), and (4) Data Collection System Transponder (DCST).
All mission instruments were found to be satisfactory during mission
check period (three months after the launch) though there was
interference problem in DCS due to the outer radio interference source
which was resolved by changing the frequency of Data Collection platform
(DCP) .
NASDA planned and initiated MOS-1 Verification Program (MVP) to evaluate
MOS-1 observation system since March, 1987. NASDA is conducting MVP in
collaboration with joint research organizations, domestic and foreign
organizations. As a part of the MVP, NASDA conducted airborne
experiments in summer and winter in several test sites in FY 1987 in
Japan on passing days of MOS-1 and will conduct summer airborne
experiment in FY 1988. The first symposium for MVP was successfully
conducted by NASDA on November 10 and 11, 1987 in Tokyo. The second
symposium will be held in July 12, 13 and 14, 1988 in Tokyo Yubin Tyckin
Kaikan in Hamamatsucho, Tokyo near NASDA Headquarter and the third final
symposium will be held in February, 1989.

MESSR

The MESSR is an electronic-scanning radiometer using CCD detector
elements with the four bands (1)0.51-0.59 um, (2) 0.61-0.69 um,
(3) 0.72-0.80 um, and (4) 0.80-1.1 um. Nominal spatial resolution is
50m. The main mission objectives of the MESSR is to observe land
surface and sea conditions such as transparence.

VTIR

The VTIR is a mechanical scanning type radiometer to observe in one
visible(band 1:0.5-0.7 um) and three thermal infrared bands (band
2:6.0-7.0 um, band 3:10.5-11.5 um, band 4:11.5-12.5 um). The nominal
spatial resolution is 900m for band 1 and 2700m for band 2, 3 and 4.
The main objective of VTIR is to observe sea surface temperature, cloud,
upper atmosphere and others.

36 EC09C
82 E051A Marine Observation Satellite (MOS-1)

In MOS-1, three types of imaging radiometers are installed: a visible and thermal inflared radiometer (VTIR) which takes pictures of the ocean, and clouds in one visible and three thermal infared bands and measures the temperature of the ocean or cloud tops; a multispectral electronic selfscanning radiometer (MESSR) for visible and near infrared bands forcartography; and a microwave scanning radiometer (MSR) for measuring sea surface temperature when it is cloudy.

Visible and Thermal Infrared Radiometer (VTIR)
The VTIR installed in MOS-1 has one visible band (wavelength = 0.5 0.7um) and three thermal infrared bands (wavelength = 6.0-7.0 um, 10.5-11.5 um, and 11.5-12.5 um). Images of clouds, water vapor and the temperature on the sea surface or cloud tops are obtained using this sensor.

The VTIR uses a rotating mirror scanner, a Ritchey-Chretien telescope (a reflecting optical system), radiatively cooled mercury cadmium tellununl (HgCdTe) infrared detectors, and silicon PIN diode.Theinstantaneous field of view (IFOV) on the earth is 900 m for the visible band and 2700m for infrared bands, and the scan width is about 1500km.

The scanning radiometer consists of a scan mirror, its driving motor, a black-body raditor for reference, focusing mirror, filters, relay lenses and detectors mounted on the radiation cooler.

Infrared radiation from the target is conducted to the cooled mercury cadmium tellunum (HgCdTe) detector. Visible light is directly conducted to a silicon PIN diode from the focusing mirror.

Radiation cooler (RC) has the function to cool down the detector temperature by thermal energy radiation into space. The RC temperature is balanced, when the energy input to the detectors is equal to the thermal energy radiated from them. Detectors are then cooled to an ultralow temperature (about 115 K) for operation.

Infrared detectors are mounted on the RC, which is cooled to about 115K. The VTIR's RC has two stages: the stage-1 temperature is about 150K, and that for stage-2 is about 115 K.

The sensor observes the earth when the mirror faces in that direction and calibrates to the reference black-body when the mirror faces it.

Electrical signals from the detectors are amplified, converted to digital, and multiplexed for transmission.

61 E032B
105 E058D THIS ARTICLE WAS WRITTEN BY THE PERSON INDICATED IN THENAME FIELD. THE ARTICLE CAME FROM THE 1988 JOINTCONVENTION RECORD OF INSTITUTE OF ELECTRONICS ANDINFORMATION ENGINEERS OF JAPAN.
58 E031. Eight to twelve-micron infrared detectors using high quality CdHgTe epitaxial wafer

The 11-V1 compound semiconductor CdHgle(CMT) is a promising material for detectors in the 8-12um

spectral region. The performance of the detector depends greatly on the quality of the material and the structure of the device. We present our recent results concerning photoconductive (PC) and photovoltaic (PV) detectors.

For a useful PC detector, one must reduce the surface recombination and increase the diffusion length of of the minority carrier. Since the former problem has already been solved by forming an anodic oxide layer on the CMT surface, we concentrated on the latter.

In an ideal crystal with no defects, the excess carriers generated by IR absorption diffuse some length and recombine by an Auger process. However, in an actual crystal with many defects, carriers may recombine at the defects. Using the liquid phase epitaxy (LPE) method, we prepared CMT epitaxial wafers having different etch pit densities (EPDs) corresponding to the threading dislocations in the CMT epitaxial layer. The PC detector consisted of two separated electrodes and a detection section.

The detectiviy remained constant with and EPD of < 10^5 cm^-2 and decreased with an EPD of more than the value. An EPD of 10^6 cm^-2 provides an average length among threading dislocations of 30um. This value is near the diffusion length of 20um limted by Auger recombination of the minority carrier We propose a simple model where the threading dislocation is the recombination center. That is, with an EPD of over 10^6 cm^-2, excess carrier recombine dislocations. With an EPD below the value, theyy recombine by Auger processes. Lowering the EPD, we have produced high performance detectors having the detectivity of Dblip

For PV detectors, the most important matter is the reduce the surface leakage current. At the surface, the tunnel or g-r current increases through the sur face state and the fixed charge.

We have prepared by LPE wafers having double CMT epitaxial layers. The band gap of the second p-type layer is wider than that of the first p-type layer. The pn junction was formed by removing the second layer of 100-um thickness to reach the first layer followed by indium diffusion. The surface state of the first layer might be greatly reduced, because the lattice mismatch between the two layers is negligible. The fixed charge on the first layer does not exist, because the second layer is semiconducting. In practice, the leakage currnt of this structure decreased to about one-tenth compared with that of conventional structures using a single epiaxial layer.

63 E033A GMS-3 is a spin-stabilized geostationary meteorological satellite with mechanical despun antennas. GMSS-3 will be thde GMS-2 protoflight spacecraft refurbished to provide more capability and modified to improve its reliability. Hence, the configuration and characteristics of the spacecraft are improved over those of the predecessor, GMSS-2 and most subsystems are night-proven.

Overall size, weight and shape of the spacecraft are designed to be compatible with N-II launch vehicles. The spacecraft length is 444 cm at launch and 345 cm on station, and the diameter is 215 cm. The weight when GMS-3 is separated from N-II third stage is approximately 681 kg, and the spacecraft dry weight

on station is approximately 287 kg.

The spinning section includes VISSR and supporting subsystems. The forward assembly consists of VISSR, magnesium thrust tube, honeycomb equipment shelf, electronics, batteries, main wire harness, Reaction Control Subsystem (RCS) tanks and thrusters, solar panel, and thermal barriers. The aft assembly includes an Apogee Kick Motor (AKM), wire harness, AKM adapter, and separation hardware. The aft assembly is jettisoned after motor burnout.

The satellite mission life is 4--5 years due to the limited amount of on-board hydrazine fuel; however, the design life is 5 years. Redundancy of mission-critical functions is provided to ensure electronics lifetimes significantly in excess of 5 years. The solar panel power of 263 W includes an approximately 16W margin at the end of 5 years (summer solstice)

VISSR

The Visible and Infrared Spin Scan Radiometer (VISSR) is used to obtain visible and infrared spectrum mappings of the earth and its cloud cover with specially designed optical telescopes and detector system. A complete 20 x 20 degree scan of the full earth disk can be accomplished every 30 minutes utilizing the spacecrafts 100 rpm spin motion for east-west scans. Primary scanning requires 25 minutes, mirror retrace 2.5 minutes, and spacecraft stabilization another 2.5 minutes.

Using its scan, primary, and secondary mirrors, the optical telescope collects visible and infrared energy from images of the earth's surface and brings these images into focus at the focal plane. Visible fiber optics and infrared relay optics reley images from the telescope focal plane to redundant visible and infrared detectors. Photomultiplier Tubes (PMT) detectors convert visible light into visible analog signals, and HgCdTe detectors, cooled by a radiation cooler, converts the earth's radiation into infrared analog signal. The VISSR outputs are feed to VISSR Digital Multiplexer (VDM) unit., which is internally redundant, for processing.

VISSR CHARACTERISTICS

Function --- Provide Visible & Infrared spectrum mapping of earth & cloud cover

	Visible Channels	Infrared Channels
Field Of View	35 x 31 urad	140 x 140 urad
Band	0.50 to 0.75u	10.5 to 12.5 u
Resolution	1.25km	5.0 km
Scanning Lines	2500 x 4	2500
Scan Step repeat	+-1.8urad	+-1.8 urad
Noise Performance	S/N>=45 alb=100%	NE T<+0.5K 300K
	S/N>=6.5 alb=2.5%	NE T<+1.5K 220K

49 E027E Status of Development

The acceptance test (AT) of the night biodel (FM) was completed in April 1986 and FM was transported to the Tanegashima Space Center in May and awaits the launch. Details of each of the observation radiometers and the data collection systems tranponder
are as follows:

2) VTIR

The VTIR is a mechanical scanning type radiomeeter to observe in one visible and three thermal infrared bands and the detector has silicon PIN diodes for the visible band and HgCdTe for the thermal infrared bands. It mounts a radiation cooler to cool the IR detector to about 110K to obtain necessary performance, which is exposed to space. The structure of the VTIR is as indicated below

The ground surface resolution of the VTIR is about 1km fot the visible band and about 3km for the thermal infrared bands. Scanning is handled by the scanning mirror, rotating at 7.3 RPS. Received light passes through the telescope section composed of the main mirror and the

secondary mirror, and is divided into the individual bands to be converted to electrical signals by the detectors. VTIR data are transmitted to ground stations through the signal processor.

The calibration signals are produced by internal black body measureed and space measurement when the scanning mirror is not facing the Earth.
VTIR may be operated at 16 different gains. VTIR MAJOR COMPONENTS AND FUNCTIONS

Component	Function
Optics individual filters	Energy reflected by rotating scan mirror is tranfered through the Richey-Chretien optical system and seperated into bands with dichroic and light splitting
Detector (visble)	Incoming energy detected by Si-PIN diodes and HgCdTe detector (Infrared)
Amplifier amplifier for electrical	Individual preamplifier and main each band, gain select switching, calibration signal input.
Synchronization scanning Synchronized scanning	Composed of timing signal generator unit, drive unit, and scanning unit. through scan start signal generated by unit chopper.
Calibration calibration control	Reference heat source for IR channel composed of blackbody and black body

Radiation cooler space | Cools IR detector to about ... in a environment with passive cooler.

Signal Processor — Image signals created by the detectors are amplified, PCM coded and sent to the MESSR signal processor

Power Source — Stable power supply to the individual components

Table4

Item	Performance	
	Visible	Infrared
Wavelength	0.5-0.7	6.0- 7.0 10.5 - 11.5 11.5 - 12.5
IFOV (mrad)	1 +-0.1	3 +- 0.3
Swath width(km)	1500	
Scanning method	Rotating Mirror	
Scan period	1/7.3 sec	
Detector	Si-PIN diode	HgCdTe
Optics	Ritchey-Chretien	
S/N	>55dB (albedo=80%)	-
NE Chg T	-	<0.5K(at 300K)
Quantization level	256 (8 bits)	256 (8 bits)
Data Rate	0.8	

5 E000C IR DETECTOR - PHOTOCONDUCTOR -GaAs

GaAs, Gallium Arsenide detectors have the most promise as the detector in laser communication applications

(SEE PHOTOCONDUCTOR DISCUSSION ON SHEET A)

6 E0000 IR DETECTOR - PHOTOCONDUCTOR - DOPED SILICON

These detectors will have characteristics that vary over the ranges indicated depending on the type of dopant. Typical dopants are: As (arsenic), B (boron), Ga (gallium), Sb (tin), In (indium), and P (phosphorus).

(SEE PHOTOCONDUCTOR DISCUSSION ON SHEET A)

33 E004C Outline of MOS-1 Verification Program (MVP)

Abstract

Marine Observation Satellite 1 (MOS-1) was successfully launched

from Tanegashima Space Center, NASDA by N-II launch vehicle at 10:23 JST (1:23 UT) on February 19, 1987. The MOS-1 has 4 mission instruments: (1) Multi-Spectral Electronic Self Scanning Radiometer(MESSR), (2) Visible and Thermal Infrared Radiometer(VTIR), (3) Microwave Scanning Radiometer(MSR), and (4) Data Collection System Transponder (DCST). All mission instruments were found to be satisfactory during mission check period (three months after the launch) though there was interference problem in DCS due to the outer radio interference source which was resolved by changing the frequency of Data Collection platform (DCP) . NASDA planned and initiated MOS-1 Verification Program (MVP) to evaluate MOS-1 observation system since March, 1987. NASDA is conducting MVP in collaboration with joint research organizations, domestic and foreign organizations. As a part of the MVP, NASDA conducted airborne experiments in summer and winter in several test sites in FY 1987 in Japan on passing days of MOS-1 and will conduct summer airborne experiment in FY 1988. The first symposium for MVP was successfully conducted by NASDA on November 10 and 11, 1987 in Tokyo. The second symposium will be held in July 12, 13 and 14, 1988 in Tokyo Yubin Tyokin Kaikan in Hamamatsucho, Tokyo near NASDA Headquarter and the third final symposium will be held in February, 1989.

MESSR

The MESSR is an electronic-scanning radiometer using CCD detector elements with the four bands (1)0.51-0.59 um, (2) 0.61-0.69 um, (3) 0.72-0.80 um, and (4) 0.80-1.1 um. Nominal spatial resolution is 50m. The main mission objectives of the MESSR is to observe land surface and sea conditions such as transparence.

VTIR

The VTIR is a mechanical scanning type radiometer to observe in one visible(band 1:0.5-0.7 um) and three thermal infrared hands (band 2:6.0-7.0 um, band 3:10.5-11.5 um, band 4:11.5-12.5 um). The nominal spatial resolution is 900m for band 1 and 2700m for band 2, 3 and 4. The main objective of VTIR is to observe sea surface temperature, cloud, upper atmosphere and others.

35 E009B
27 E005B A new field radiometer has been developed to provide ground truth data for the optical sensor of the Japanese ERS-1

(Earth Resources Satellite), which is scheduled to be launched in 1992. This radiometer has two motor-driven filter wheels, each of which can contain up to eight filters and corresponds to the silicon and lead-sulphide detectors respectively. The same field of view exactly is guaranteed to all the spectral bands, because only one aperture is used to observe a target. It takes approximately twenty seconds to perform one continuous measurement for the seven spectral bands equivalent to the ERS-1 sensor. A portable lap-top computer controls the radiometer and records measured results on a floppy disc. An officially-calibrated lamp and a standard reflection plate mounted on an optical bench were also prepared for the purpose of absolute energy calibration of the radiometer. Preliminary investigation has shown that this newly developed radiometer can provide reliable spectral data.

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29 E029A

ABSTRACT

High quality n-type CdHgTe epi-layers doped with In below 0.1 ppm, whose carrier concentration and mobility at 77 K are below 4 x 10^14 cM^-3 and over 2 x 10^5 cm^2/V.S , respectively, have been grown by .LPE on CdTe (111) B substrates with EPDs below 10^5 cm^-2 . A new result obtained is that long carrier diffusion length is essentially inportant for realizing a high performance detector, whose detectivity reaches to D*BLIP .

INTRODUCTION

Ternary compound, CdxHg1-xTe (CMT) , has ever been noticed as a high quality material for an infrared detector . Especially, CMT having the composition of x=,0.2 is important for a 10pm region infrared detector, which has high detectivity in the 8-14um wavelength region corresponding to "atmospheric window".

Since detectivity of the detector is thought to depend strongly on the properties of CMT, firstly, the condition to grow high quality CMT was studied, next, influential factors of CMT on the detectivity of the 10 um region PC type

detector were investigated.

CONCLUSION

(1) High quality CMT epi-layers were obtained by doping small amounts of In and using CdTe substrates with low EPDs.

(2) Long carrier diffusion length is essentially important for a high detectivity PC type IR detector.

7 E0000 IR DETECTOR - LINEAR ARRAY - PHOTODIODE

Linear arrays may be used in two different system designs. The first, and most common, is parallel scan (also called pushbroom) where the line of adjacent detector cells are perpendicular to the direction of motion of either the sensor or the platform on which the sensor is mounted. In this mode the target is imaged by this array of cells in which each cell responds to IR radiation being received from a line of the scene that corresponds to the width of the detector cell and runs parallel to the scan direction.

The other application is known as serial scan or "time delay and integration" in which the linear array of detectors is aligned parallel (rather than perpendicular) to the direction of scan. This results in each successive detector cell in the array being exposed to the same point in the target scene, but with a time delay determined by the scan speed. The signal from each element is delayed by the time the image takes to move from one element to the next, and then is added to the signal from the next element. In this scheme the signal will increase in proportion to the number of elements, while the noise adds as the square root, so that the signal-to-noise ratio will improve as the square root of the number of elements. However, in this system design the array must also be scanned in the opposite (perpendicular) direction to create a two dimensional image.

Serious problems that must be overcome with all arrays are:
- nonuniformity of response from cell to cell
- limitations on cell resolution
- crosstalk between adjacent cells

The response of individual detectors cells may vary to such an extent across the array that calibration of individual cells and compensation for each output signal is usually required for radiometric systems.

115 E059B
116 E059C
114 E059A
16 E003A The great success of the Infared Astronomical Satellite (IRAS) has demonstrated that a cryogenically cooled infra-red telescope in space possesses tremendous capabilities in infra-red astronomical observation. Prpjects for the next generation, the SIRTF and the ISO, are now being planned by NASA and ESA, respectively. They are designed for general astronomical use equipped with multi-facilities. The Infra-red Telescope in Space (IRTS) is planned to be dedicated to an advanced infra-red astronomical observation; it will be launched on board the Space Flyer Unit (SFU) in early 1993, which is a re-usable free flyer designed as a multi-purpose common facility for scientific and engineering experiments. The IRTS is equipped with a small-sized telescope with a primary mirror of 15 cm and having a wide field of view

suitable for the observation of diffuse IR sources. The major observational objectives extend in the wavelength from near infra-red to far infra-red regions. The characteristic feature of the IRTS is cryogenic cooling down to 1.8K by stored superfluid helium (He II) to provide it with both the maximum sensitivity and the capability of making spectroscopic observations in far infra-red regions.

17 E003B
48 E027D Status of Development

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are as follows:

2) VTIR

The VTIR is a mechanical scanning type radiomeeter to observe in one
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infrared bands. It mounts a radiation cooler to cool the IR detector
to about 110K to obtain necessary performance, which is exposed to
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The ground surface resolution of the VTIR is about 1km fot the visible
band and about 3km for the thermal infrared bands. Scanning is handled
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secondary mirror, and is divided into the individual bands to be converted to electrical signals by the detectors. VTIR data are transmitted to ground stations through the signal processor.

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and space measurement when the scanning mirror is not facing the Earth.
VTIR may be operated at 16 different gains. VTIR MAJOR COMPONENTS AND FUNCTIONS

Component	Function
Optics	Energy reflected by rotating scan mirror is tranfered through the Richey-Chretien optical system and seperated into
individual	
	bands with dichroic and light splitting
filters	
Detector (visble)	Incoming energy detected by Si-PIN diodes
	and HgCdTe detector (Infrared)

Amplifier amplifier for electrical	Individual preamplifier and main each band, gain select switching, calibration signal input.
Synchronization scanning	Composed of timing signal generator unit, drive unit, and scanning unit.
Synchronized scanning	through scan start signal generated by unit chopper.
Calibration calibration control	Reference heat source for IR channel composed of blackbody and black body
Radiation Cooler space	Cools IR detector to about 110K in a environment with passive cooler.
Signal Processor are amplified processor	Image signals created by the detectors PCM coded and sent to the MESSR signal
Power Source components	Stable power supply to the individual

Table4

Item	Performance	
	Visible	Infrared
Wavelength	0.5-0.7	6.0- 7.0 10.5 - 11.5 11.5 - 12.5
IFOV (mrad)	1 +-0.1	3 +- 0.3
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Detector	Si-PIN diode	HgCdTe
Optics	Ritchey-Chretien	
S/N	>55dB (albedo=80%)	-
NE Chg T	-	<0.5K(at 300K)
Quantization level	256 (8 bits)	256 (8 bits)
Data Rate	0.8	

126 E066C We have demonstrated the first photovoltaic IR-sensor arrays fabricated in single-crystalline PbS layers grown epitaxially on Si substrates. The achieved detctivities are within a factor of 3 of published

values in bulk PbS sensors or epitaxial PbS sensors on bulk BaF_2 substrates. However, all these sensitivities still lie considerably below the theoretical values. They may be increased by at least an order of magnitude by improving material quality device processing, and by applying antireflection coatings. PbS-on-Si structures seem very promising for a heteroepitxial, but monolithic IR-focal plane array in the short-to mid-IR range with the signal processing electronics integrated in the Si substrate. Contrary to other monolithic Si-based solutions like silicide sensors, quantum efficiencies are large and the system can be operated at rather high

8 E000 IR DETECTOR - LINEAR ARRAY - CHARGE COUPLED DEVICE

The charge coupled device (CCD) is a specialized semiconductor capacitor array capable of storing and transferring analog or digital signals from photoelectronic inputs. The CCD stores and moves packets of charge, either electrons or electron holes, across its length, maintaining the pattern and intensity of the original input. This makes it an excellent information collection, storage and transmission device. In the IR detector this information packet is a picture element, produced when light strikes a photovoltaic material and produces a quantity of electrons equivalent to the intensity of the light.

CCD's offer many advantages including high sensitivity, high quantum efficiency, and low noise. They are small and light weight, have high reliability and low power consumption and permit precise geometric registration.

IR CCD Materials

They are produced as either monolithic or hybrid devices. Monolithic IR CCD devices are those in which both the photodetection, and the charge generation as well as the charge transfer are achieved in a structure built around a one-material system. While silicon is the standard material for the CCD portion of the device, a hybrid configuration would utilize a different material for the photodetector, although the monolithic device would very likely employ a doped silicon detector. InSb and HgCdTe are possible candidates for the hybrid devices. A broad variety of devices are under development including:

- Monolithic IR CCD
    - Extrinsic-Silicon
    - Intrinsic IR CCD using Narrow-Bandgap Materials
        - InAs, InSb, HgCdTe
    - Schottky_barrier IR CCD
- Hybrid IR CCD
    - Direct Injection
    - Buffer Interface

Cooling Requirements

While IR CCD's boast many advantages they are hampered by a requirement that the detector be cooled to cryogenic temperature. For example, doped silicon detectors operating in the 8 to 14 uM region require a temperature between 15-30 K while those operating in the 3-5 uM region require a temperature between 40 and 65 K.

31 E004A Outline of MOS-1 Verification Program (MVP)

Abstract

Marine Observation Satellite 1 (MOS-1) was successfully launched from Tanegashima Space Center, NASDA by N-II launch vehicle at 10:23 JST (1:23 UT) on February 19, 1987. The MOS-1 has 4 mission instruments: (1) Multi-Spectral Electronic Self Scanning Radiometer(MESSR), (2) Visible and Thermal Infrared Radiometer(VTIR), (3) Microwave Scanning Radiometer(MSR), and (4) Data Collection System Transponder (DCST).

All mission instruments were found to be satisfactory during mission check period (three months after the launch) though there was interference problem in DCS due to the outer radio interference source which was resolved by changing the frequency of Data Collection platform (DCP).

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VTIR

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The main objective of VTIR is to observe sea surface temperature, cloud, upper atmosphere and others.

95 E0563 Infrared FLIR Development

The Defense Agency, Mitsubishi Electric Co. [MELCO] and Fujitsu have begun reseach fabrication of a forward-looking surveillance device that uses an infrared sensor (FLIR) to be mounted on fighter aircraft. It is characterized by the dual functions of surface surveillance and air to air surveillance and, taking advantage of the Japanese specialties of semiconductors and graphic processing technology, will be the world's most advanced system. If the trial fabrication is successful, development will be hurried along and the device will be mounted in the next fighter support aircraft (FSX) and the future fighter attack aircraft. Along with MELCO and Fujitsu, both NEC and Toshiba have advanced technology in the field of infrared sensors. These four companies submitted independent proposals for the FLIR research fabrication, competing for acceptance, but in the end MELCO and Fujitsu were chosen as prime contractor and cooperating contractor respectively, and were able to start research. They intend to build a working version in about three years, then shift to the development stage.

The FLIR for fighters is a device that assures vision even at night and in poor weather. It uses a sensor to detect the infrared radiation naturally emitted by bodies, and uses graphic processing to display images that can be distinguished visually on a television monitor. Even at night, the images are as clear as day. Infrared surveillance devices have become practical for use in surface weapons like tanks, but a FLIR to be mounted in a fighter requires faster image processing, better discrimination, and resistance to environmental factors.

With the advance of semiconductor technology, infrared sensors have developed from the first generation of single element detection, through the second element of multicell detection in linear anays, to the third generation of IRCCD (infrered charge-coupled devices). At present the world at large is shifting from the second generation to the third. The Japanese effort will make a high-performance IRCCD practical, and will achieve a FLIR with greater sensitivity and, with smaller size and weight than those now in use, which requie mechanical scanning.

Two IRCCD's to detect infrared wavelengths in the 3 to 5 micron band and in the 8 to 12 micron band will be mounted in a single pod. That will yield a FLIR capable of detecting a broad range, with both air-to-surface and air-to-air functions. Those under development in Europe and the U.S. are regarded as exclusively for ground or for air targets. MELCO is responsible for trial fabncation of the 3 to 5 micron IRCCD, and Fujitsu for that in the 8 to 12 micron band.

30 E024B MILITARY R&D

TRDI STARTS RESEARCH ON FLIR SYSTEM

The Defense Agency's Technical R&D Institute (TRDI) has started research, including prototype fabrication, on a forward looking infrared (FLIR) system for installation in fighter aircraft.

TRDI will promote the FLIR research program in cooperation with two major Japanese electronics manufacturers--Mitsubishi Electric Corp.(MELCO) and Fujitsu Ltd.

The planned FLIR system is capable of both air and ground surveillance. Fully using Japan's advanced technology such as semiconductors and image processors, TRDI is expected to make the world's most advanced system in this kind.

If and when prototype fabrication should be successfully completed, TRDI is expected to urge development of the system with a view to installation in the FS-X next support fighter and other mainstay fighter aircraft in the future.

In addition to MELCO and Fujitsu, NEC Corp. and Toshiba Corp. also have advanced technology in infrared sensors. These four electronics manufacturers competed for the FLIR research contract based on their respective research experience.

After all, MELCO won the prime contract, while Fujitsu was designated as a cooperative firm. TRDI plans to fabricate a prototype system in three years to confirm technical feasibility of the system and then move to full-scale development.

The FLIR system is aimed at assuring good visibility even at night and in adverse weather. The system is designed to detect infrared rays of objects and to apply image processing to allow identification with naked eyes on TV monitors.

For land force weapons like tanks, infrared night vision devices are already available. For the FLIR system, on the other hand, high-speed image processing, high identification capability and durability are required since it will be used aboard fighter aircraft.

Compared with conventional infrared sensors, the TRDI-designed FLIR system will be more sensitive and small in size and light in weight by using advanced IRCCD (infrared charge-coupled device).

TRDI plans to place two types of IRCCD in the same pod. One is to detect infrared ray in 3-5 micron wave length and the other is to detect that in 8-12 micron wave length.

With these two types of IRCCD, the FLIR system will be able to detect infrared ray in wider ranges of wave length and will be capable of both air and ground surveillance. MELCO is responsible for fabrication of 3-5 micron band IRCCD and Fujitsu for 8-11 micron band IRCCD.

40 E013A MOS-1 and MESSR

NASDA (National Space Development Agency of Japan) launched MOS-1 (Marine Observation Satellite 1) in 1987. Before the launching, NASDA conducted MOS-1 airborne verification experiment in order to test sensor equipment. GSI (Geographical Survey Institute of Japan) took part in the experiment, and evaluated resolving power of MESSR (Multi-spectral Electric Self-scanning Radiometer). It is a visible and infrared image sensor on the MOS-1. Table 1 is selected technical data of the MOS-1 and the MESSR.

The MESSR employed linear CCD (Charge Coupled Device) sensor like SPOT HRV. One of the most significant difference between

linear CCD sensor and scanner (ex. LANDSAT MSS, TM) is following. Scanner samples incident light in IFOV (Instantaneous Field of View) in a moment. But CCD accumulates incident light in IFOV while satellite moves detector observes changes during the accumulation. It contributes to lower resolving power in flying direction, but no contribution in perpendicular to the fling direction.

SELECTED TECHNICAL DATA OF THE MOS-1 & MESSER

LAUNCH DATE	
ORBIT HEIGHT	02-19-87
WAVE LENGTH	909 KM
	0.51-0.59 BAND1
	0.61-0.69 BAND2
	0.72-0.80 BAND3
SCAN WIDTH	0.80-1.10 BAND4
IFOV	100KM x 2 SYSTEMS
QUANTIZATION LEVELS	54.7 urad
DETECTOR	64
SCAN PERIOD	2048 CELLS LINEAR CCD
	7.6 m sec.

41 E013B MOS-1 and MESSR

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ORBIT HEIGHT	02-19-87
WAVE LENGTH	909 KM
	0.51-0.59 BAND1
	0.61-0.69 BAND2
	0.72-0.80 BAND3
SCAN WIDTH	0.80-1.10 BAND4
IFOV	100KM x 2 SYSTEMS
QUANTIZATION LEVELS	54.7 urad
DETECTOR	64
SCAN PERIOD	2048 CELLS LINEAR CCD
	7.6 m sec.

112 E058K THIS ARTICLE WAS WRITTEN BY THE PERSON INDICATED IN THENAME FIELD. THE ARTICLE CAME FROM THE 1988 JOINTCONVENTION RECORD OF INSTITUTE OF ELECTRONICS ANDINFORMATION ENGINEERS OF JAPAN.

One-dimensional Image Sensors:

These scanners have various uses in such things as facsimile, computer-input scanners and copying machines, and there are the reduction-reading type, which reads the original with the help of lens optical systems, and the ......

type, which reads directly without reducing the original. The contact type can be divided into thefilm-contact method, which forms a single sensor by usingsuch large-area semiconductor films as CdS-Se film andamorphous Si film (a-si film), and the multi-chip method,which lines up a multiple number of crystal semiconductorchips such as CCD. The contact type, development of whichhas been greatly promoted over the last 10 years, has the advantage that, compared with the reduction type, designand adjustment of the optical system is easier, so one can attempt to miniaturize it. On the other side of thecoin, it has the disadvantage that a great deal of wiringbecomes necessary connecting the IC to the drive-IC,which is attached outside, and to the light-receiving part. The kind of contact-type sensor shown in figure 3(not shown) has been developed recently in order to
eliminate this point. This sensor ,integrates on the samesubstrate a PIN optical diode and a shift register forscanning, which is composed of a multi-crystal Si thin-film transistor; a maximum scanning speed of up to 2 MHZhas been obtained. Furthermore, by using an n-typea-Sic:H for the n-layer of the PIN optical diode, itprevents the injection of holes from the Al electrode, and obtains a low dark current (10^-13A/mm^2) and alight/dark ratio of 5 digits or greater.

15 E001A Earth observation from space by satellite is one of the central themes of space exploration, and covers meteorological observation, oceanographical observation and geodetic surveillance.

The Ministry of International Trade and Industry (MITI) and NASDA are jointly pursuing the development of the Earth resources satellite ERS-1 to ensure that resources-poor Japan can secure its resources for the future. The satellite will also monitor agriculture, forestry and fisheries, undertake coastal surveillance, and provide data useful in preventing natural disasters.

This year, full-fledged development of a proto-flight model has commenced, aiming for a scheduled launch in February 1992 by H-I rocket. It will be placed in a Sun-synchronous orbit at an altitude of 568 km and at an inclination of 97.7 deg.

MITI is taking charge of developing observation systems for the ERS-1. These comprise a synthetic aperture radar and two optical sensors.

Optical Sensors

The OPS comprises a visible and near infrared radiometer, and a short-wavelength infrared radiometer. These radiometers are equipped with electronic scanners using charge-coupled devices of 4,096 elements as detectors.

The OPS will be used mainly for the exploration of mineral resources, taking high-resolution stereoscopic images by detecting solar reflection from the ground.

Number of Observation bands	3 visible and near infrared bands 1 stereo-vision band 4 shortwave infrared bands
Resolution	18.3m X 24.2m
Swathwidth	75 km
Quantization	6bits
Output data rate	20 Mbps x 2 ch

Base height ratio 0.3
in stereoscopic
imaging

94 E056A Infrared FLIR Development

The Defense Agency, Mitsubishi Electric Co. [MELCO] and Fuitsu have begun reseach fabrication of a forward-looking surveillance device that uses an infrared sensor (FLIR) to be mounted on fighter aircraft. It is characterized by the dual functions of surface surveillance and air to air surveillance and, taking advantage of the Japanese specialties of semiconductors and graphic processing technology, will be the world's most advanced system. If the trial fabrication is successful, development will be hurried along and the device will be mounted in the next fighter support aircraft (FSX) and the future fighter attack aircraft. Along with MELCO and Fujitsu, both NEC and Toshiba have advanced technology in the field of infrared sensors. These four companies submitted independent proposals for the FLIR research fabrication, competing for acceptance, but in the end MELCO and Fujitsu were chosen as prime contractor and cooperating contractor respectively, and were able to start research. They intend to build a working version in about three years, then shift to the development stage.

The FLIR for fighters is a device that assures vision even at night and in poor weather. It uses a sensor to detect the infrared radiation naturally emitted by bodies, and uses graphic processing to display images that can be distinguished visually on a television monitor. Even at night, the images are as clear as day. Infrared surveillance devices have become practical for use in surface weapons like tanks, but a FLIR to be mounted in a fighter requires faster image processing, better discrimination, and resistance to environmental factors.

With the advance of semiconductor technology, infrared sensors have developed from the first generation of single element detection, through the second element of multicell detection in linear anays, to the third generation of IRCCD (infrered charge-coupled devices). At present the world at large is shifting from the second generation to the third. The Japanese effort will make a high-performance IRCCD practical, and will achieve a FLIR with greater sensitivity and, with smaller size and weight than those now in use, which requie mechanical scanning.

Two IRCCD's to detect infrared wavelengths in the 3 to 5 micron band and in the 8 to 12 micron band will be mounted in a single pod. That will yield a FLIR capable of detecting a broad range, with both air-to-surface and air-to-air functions. Those under development in Europe and the U.S. are regarded as exclusively for ground or for air targets. MELCO is responsible for trial fabncation of the 3 to 5 micron IRCCD, and Fujitsu for that in the 8 to 12 micron band.

29 E024A MILITARY R&D

TRDI STARTS RESEARCH ON FLIR SYSTEM

The Defense Agency's Technical R&D Institute (TRDI) has started research, including prototype fabrication, on a forward looking infrared (FLIR) system for installation in fighter aircraft.

TRDI will promote the FLIR research program in cooperation with two major Japanese electronics manufacturers--Mitsubishi Electric Corp.(MELCO) and Fujitsu Ltd.

The planned FLIR system is capable of both air and ground surveillance. Fully using Japan's advanced technology such as semiconductors and image processors, TRDI is expected to make the world's most advanced system in this kind.

If and when prototype fabrication should be successfully completed, TRDI is expected to urge development of the system with a view to installation in the FS-X next support fighter and other mainstay fighter aircraft in the future.

In addition to MELCO and Fujitsu, NEC Corp. and Toshiba Corp. also have advanced technology in infrared sensors. These four electronics manufacturers competed for the FLIR research contract based on their respective research experience.

After all, MELCO won the prime contract, while Fujitsu was designated as a cooperative firm. TRDI plans to fabricate a prototype system in three years to confirm technical feasibility of the system and then move to full-scale development.

The FLIR system is aimed at assuring good visibility even at night and in adverse weather. The system is designed to detect infrared rays of objects and to apply image processing to allow identification with naked eyes on TV monitors.

For land force weapons like tanks, infrared night vision devices are already available. For the FLIR system, on the other hand, high-speed image processing, high identification capability and durability are required since it will be used aboard fighter aircraft.

Compared with conventional infrared sensors, the TRDI-designed FLIR system will be more sensitive and small in size and light in weight by using advanced IRCCD (infrared charge-coupled device).

TRDI plans to place two types of IRCCD in the same pod. One is to detect infrared ray in 3-5 micron wave length and the other is to detect that in 8-12 micron wave length.

With these two types of IRCCD, the FLIR system will be able to detect infrared ray in wider ranges of wave length and will be capable of both air and ground surveillance. MELCO is responsible for fabrication of 3-5 micron band IRCCD and Fujitsu for 8-11 micron band IRCCD.

14 E002A
19 E021A MOS- 1 Marine Observation Satellite

MOS-1, Japan's first Earth observation satellite, was launched by the two-stage N-II launch vehicle from Tanegashima Space Center on 19 February 1987. An experimental spacecraft designed as a technology test bed for Earth observation systems, MOOS-1 carries out observations of such properties as ocean color and temperature.

The 740-kilogram satellite was launched into sun-synchronous

subrecurrent orbit and circles the Earthe 14 times each day, covering the entire surface in a 17-day period. The satellite's mission design life is two years. The development of MOS- Ib, a follow-on to MOS- 1 slated for launch in 1989, is currently under way.

Objectives of the MOS-1 program include:

* Development of sensors, verification of their performance, and experimental observation oft the Earth - in particular the oceans--using these sensors

* Basic testing of the data collection system (DCS)

* Establishment of fundamental technologies for Earth observation satellites, including

  -- Techniques for placing satellites into sun-synchronous orbits

  -- Tracking and control techniques for satellites in sun-synchronous orbits

  -- Techniques for operating Earth observation satellites

The MOS- 1 structure consists of a bus module and a mission module. The mission module carries the following systems:

* A multispectral electronic selfscanning radiometer (MESSR)

* A visible and thermal infrared radiometer (VTIR)

* A microwave scanning radiometer (MSR)

* A data collection system (DCS), including a transponder for relaying data received from collection platforms on the ground to other ground-based stations

The three sensors are passive radiometers which detect reflected solar rays or radiated electromagnetic waves and transmit the acquired data to Earth in real time. The MESSR monitors sea surface color and provides information on land surfaces in two visible and two near-infrared spectral bands.

The MESSR employs a multispectral optical design and a redundant configuration to obtain high volume, high-resolution images. It uses the pushbroom image acquisition technique, which is expected to become the mainstay of future radiometer design. The MESSR's twin optical systems each scan a 100 km wide strip at right angles to the direction of fight. With both systems operating, a width of 185 kilometers can be scanned. Each optical system consists of a pair of telescopes with a focal length of about 257mm, one for the visible range and one for the infrared range. The light in each telescope is focused on a 2,048-element one-dimensional charge-coupled device(CCD) sensor. The MESSR's optical system has a resolution of abcut 50 x 50 meters for each of the 14 x 15-micron pixels of the CCD sensor at an altitude of about 909 km.

23 EC21B
20 E021B
21 E021C MOS- 1 Marine Observation Satellite

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The three sensors are passive radiometers which detect reflected solar rays or radiated electromagnetic waves and transmit the acquired data to Earth in real time. The VTIR makes wide area observations of the Earth's surface in the visible and thermal infrared range to provide information on surface temperature and the distribution of atmospheric water vapor.

The VTIR sensor uses one visible mirror and three thermal infrared bands to detect thermal radiation. It is equipped with a rotating mirror which mechanically scans the Earth's surface from right to left, at right angles to the satellites direction of flight. When the mirror is not facing the Earth, it looks at an internal black body or at deep space to obtain thermal infrared calibration data. The VTIR's resolution is about 900 meters in the visible band and 2,700 meter in the thermal infrared bands. The wide scanning swath of the VTIR (1,500 km) enables it to observe a particular area continuously for ten or more days.

28 E001B CHARACTERISTICS OF OPS

NUMBER OF OBSERVATION BANDS	3 VISIBLE & NEAR INFRARED BANDS 1 STEREO-VISION BAND 4 SHORTWAVE INFRARED BANDS
RESOLUTION	18.3m x 24.2m
SWATH WIDTH	75km
QUANTIZATION	6 BITS
OUTPUT DATA RATE	20 Mbps x 2 ch
BASE HEIGHT RATIO IN STEREOSCOPIC IMAGING	0.3

45 E027A MOS-1 WILL CARRY THE FOLLOWING SENSORS

1) Multispectral Electronic Self-Scanning Radiometer(MESSR)
2) Visible and Thermal Infrared Radiometer (VTIR)
3) Microwave Scanning Radiometer (MSR)
Status of Development

The acceptance test (AT) of the night biodel (FM) was completed in April 1986 and FM was transported to the Tanegashima Space Center in May and awaits the launch. Details of each of the observation radiometers and the data collection systems tranponder are as follows:

1) MESSR

The MESSR is designed to observe in four bands in visible and near-IR wavelengths, and is an electronic-scanning radiometer using CCD (Charge Coupled Device)detector elements. Each array consists of a 2,048-element photoelectric detector, providing ground resolution of 50 meters, with a swath width of 100km.

Two MESSR systems are installed a little tilted to each other, and each has independent signal processors and transmitters.

The optics utilizes refractive lenses to receive two bands per lens. The incoming light is converted to an electrical signal by the array, and passed to the signal processor, where it is mixed with A/D converted data for other bands and VTIR signals, followed by transmission of the entire package by the 8GHz semiconductor transmitter to ground stations. The major components of the MESSR are as indicated in the tables below

MAJOR MESSR COMPONENTS AND FUNCTIONS

Component	Function
Optics	One optics is the telescope of bands 1 and 2,

refracting	and another of bands 3 and 4. The 4 telescopesforming the two syslems receive reflected solar radialion from the earth's surfaces
Light splitter bands	Light from the telescopes is split into 2 with a prism
Detector elements) the input	A total of 8 CCD arrays (each with 2,048 are mounted, with 1 per band, to convert radiance to an image signal
Control detector,	The drive signal is supplied to the CCD and the calibration signal generated
Power supply	Stable supply of power for MESSR components
Siganl processor amplfied and telemetry transmitted are amplfier.	The image signal from the detector is A/D converted multiplexed with VTIR and data, MSK modulated with 70 MHz IF, and at high speed. High and low gain settings possible by adjusting the gain of thr

MESSR CHARACTERISTICS

ITEM	PERFORMANCE
Wavelength (um)	0.51 -0.59 (Band 1) 0.61 -0.69 (Band 2) 0.72-0.80 (Band 3) 0.80-1.10 (Band 4)
IFOV (u rad)	54.7 +- 5.0
Swath width (km)	100
Scanning method	Push-broom Scanner
Optics	Refracting telescope
Detector	2,048-element CCD
S/N	39dB-15dB
Quantization level	64 (6bits)
Scanning period (msec)	7.6
Data rate (Mbit/sec)	9

46 E027B SEE PAGENO E027A - MEMO FIELD
42 E016A 2. Japanese Earth Resources Satellite-1 (JERS-1)

JERS-1 is a remote sensing satellite designed to gather image data which are useful to explore earth resources. It will be launched in 1992 in Japan. Its weight is 1.4 tons and the altitude of its orbit will be 568 km.

JERS-1 has two kinds of imaging systems. One is synthetic aperture radar (SAR) and the other is optical sensor. The wavelength of SAR is L band and the resolution of SAR image is 18 m. The swath width of both sensors is 75 km. The ground resolution of optical sensor is 18.3m x 24.0 m for the nadir looking sensor and about 19.1m x 24.0m for the forward looking sensor. The nadir looking sensor takes seven band images in the wavelengths of visible, near infrared and shortwave infrared. The forward looking sensor takes one band image in shortwave infrared wavelength.

The combination of a nadir looking sensor image and a forward looking sensor image produces stereoscopic vision. The base-to-height ratio of JERS-1 stereoscopic images is fixed to 0.3. This ratio cannot be enlarged because the nadir looking sensor and the forward looking sensor must be placed in the same telescope due to considerations of weight limitations, etc.

43 E016B SEE RECORD 41 FOR INFORMATION
44 E016C 2. Japanese Earth Resources Satellite-1 (JERS-1)

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must be placed in the same telescope due to considerations of weight
limitations, etc.

67 E0343 The MOS- 1 is the first satellite developed by Japan specifically for a remote sensing mission. The MESSR images the surface ofthe earth with four bands of the light spectrum from visual to near infrared (0.5um - 1.1um). The reflected light from the earth's surface is focused into images by the MESSR telescopes with the use of a lens system. Each telescope output light is divided into two bands by prisms and filters, and each light is focused on a detector. This new electronic scanning radiometer using CCD sensors for detectors provides a high resolution through high registration stability, wide wavelength range, and uniform picture quality.

The heart of the MESSR is the photoelectric detector which employs CCD image senors for each band. A CCD image sensor operates as both an imager and/or sequential shift register. The CCD image sensor is a LSI device made up of 2048 light sensitive CCD elements,shift register, and amplifers, all integrsted on one silicon chip and produced in the form of a dual in line package.

When CCD image sensors are used for detection the following benefits are realized :

* The positions of 2048 picture elements on one line are fixed so that the registration accuracy is extremely good.

* Each CCD image sensor section is compact, ensuring ease of wiring.

* No high voltage is required and the power consumption is low.
* One one chip construction solid-state cicuitry, each CCD image sensor provides high reliability.

* Using CCD image sensors, mechanical scanning is not required.

The Messer subsystem developed for Japan's MOS-1 system has been successfully demonstrated and tested. This subsystem currently being manufactured is capable of imaging the earth and transmitting the imagig data to ground stations for processing. The following components make up the MESSR subsytem:

* Scan Radiometer
  This unit employs telescopes and CCD image sensors which converts the object scene on the ground to an image signal.

* Signal Processor Unit
  This unit performs analog-to-digital conversion and modulation of the image signal.

* X- Band Transmitter
This unit, a high speed data tranmitter operates in the X-Band (8GHz band) and provides Watts of RF power to the satellite antenna which is oriented towards the ground.

24 E022A ERS-1 Earth Resources Satellite

ERS-1, the second Japanese earth observation satellite, is scheduled for launch in 1991 by a two-stage H-I rocket. Designed to help establish active microwave techniques for remote sensing, the ERS-1 will carry a day/night, all-weather synthetic aperture radar (SAR) and an optical sensor system (OPS) with high resolution and stereoscopic imaging capabilities. Development of the satellite is under way jointly by the Science and Technology Agency (STA) and the ministry of International Trade and Industry (MITI). The satellite is expected to be utilized for natural resource exploration, forestry, agriculture, and aquaculture applications, national land surveys, and environmental protection.

The OPS is a high-resolution stereoscopic sensor capable of collecting multispectral images by detecting solar reflections from the ground ranging from the visible to shortwave infrared. The OPS is a visible and near-infrared radiometer (VNR) and a short-wave infrared radiometer (SWIR) in which 4,096 elememt charge-coupled device electronically scans the solar reflections and transforms images into electrical signals.

The VNR, including both vertical-looking multiband sensor and a forward looking sensor, will generate a three-dimensional image. The SWIR will cover a number of bands from 1 to 3 microns, a frequency range that is highly effective for remote sensing of natural resources. Both systems are expected to have 20-meter resolutions.

OPS Specifications

Number Of Observation Bands	3 Visible & Near Infrared Bands 1 Stereo Vision Band 4 Shortwave Infrared Bands
Resolution	18.3 m X 24.2 m
Swath Width	75 km
Quantization	6 Bits
Output Date Rate	30 Mbps x 2 ch
Base Height Ratio In Stereo Scopic Imaging	0.3

25 E023A

Record# PAGENO DESCRAPPLC

25 E023A ADEOS Advanced Earth Observation Satellite

ADEOS is Japan's next-generation earth observation satellite. Currently in the conceptual and preliminary design phase, the satellite is scheduled for launch in 1993. ADEOS, weighing 2.8 tons including a mission payload of 800 kilograms, will carry two advanced optical sensors: an ocean color and temperature scanner (OCTS) and an advanced visible and near-infrared radiometer(AVNIR). In January 1988 Japan called for participation by the international community in the ADEOS program.

9 E0000 IR DETECTOR - FOCAL PLANE ARRAY - HYBRID

Focal plane arrays (also called mosiac arrays, staring arrays or framing sensors) are two dimensional arrangements of many detectors which usually operate in parallel (without any mechanical scanning required) to image a target.

In some applications these two dimensional sensors may be used as scanning sensors in the time delay and integration mode. In this mode the signal-to-noise ratio is improved by scanning the target with several detectors arrayed along the scan direction. The signal from each element is delayed by the time the image takes to move from one element to the next and then is added to the signal from the next element. The signal increases in proportion to the number of elements while the noise adds as the square root, so that the signal-to-noise ratio will increase as the square root of the number of elements.

There are four generic groups of focal plane technology, two of which incorporate CCD or CID technologies and are not considered "Hybrid" technologies. (They are covered by another brief)

The third type which is called planar-hybrid, has three sub-groups. The first subgroup employs HgCdTe implanted technology where the photodiodes are made by ion-implantation (B or Be) in which the major issues are sensitivity, non-uniformity, yield, 1/f noise, and reproducibility. Hybrid HgCdTe performance has been demonstrated, on a limited basis, as follows:

REGION	RoA PRODUCT	QUANTUM EFFICIENCY	TEMP K
MWIR	>10^6 ohm-cm^2	> 50%	77
LWIR	10^5 ohm-cm^2		40

The second sub-group is hybrid pyroelectric technology which shows a flat spectral response over the 1 to 30 micron IR region and operates at room temperature, offers standard IC processing, and low cost mass production capability but has low performance, limited frequency response, 1/f noise and microphonics. It is considered promising for commercial applications.

The third sub-group is hybrid silicon (SOXS or silicon-on-extrinsic silicon) technology, which is used for both detectors and multiplexers, as separate devices. While this group has high reproducibility and sensitivity, and reasonable (5 to 10%) yields it requires a very low operating temperature (<40K).

The fourth type of focal plane technology is also hybrid, and is called "Z-type Hybrid" technology. It has two sub-groups, stacked-ceramic and stacked-silicon. In both of these groups the detectors may be fabricated from either HgCdTe, PbS, or InSb and ceramic or silicon boards stacked in the Z direction (back from the focal plane) provide multiplexing and/or analog processing. These designs enjoy a relaxed detector and multiplexer design, mass production capabilities, and a high dynamic range, but both suffer from complex production processes and limited ease of repair.

One very important advantage of these hybrid arrays over the conventional CCD arrays is that through the inclusion of these little operational amplifiers behind each detector they make it possible to compensate for the non-uniformity of detector sensitivity, a problem that has always plagued the manufacture of focal plane arrays. This compensation is accomplished by first calibrating each detector in the array to determine the offset or bias in its output or responsivity. These quantities are stored in computer memory and used to correct the detector output to the nominal performance of the array. This capability permits the manufacture of modest sized arrays (64 x 64) with very good fill ratios and very high yields. The fill ratio defines that portion of the focal plane array surface that are active detectors.

The current approach to large , high performance, arrays in the IR region of the spectrumis structured in modular form through the assembly of "buttable" arrays that may be mounted directly adjacent to other arrays on 1,2,3 or even 4 sides, with integral "backplane" signal processing.

38 E025A Silicide/p-Si(1-X)Ge Schottky contacts were studied for using in an infrared (IR) image sensor. Si(1-X),Gg layers were grown on p-Type (100) Si substrates by using molecular beam epitaxy (MBE). Schottky barrier heights of PtSi(Ge) or PdSi(Ge)/p-Si,-,Gg contacts decreased as the Ge content increased. When the Si,-,Gg layer was strained, the barrier height was smaller than when relaxed for the same value of x. These results suggest the possibility of a long wavelength (8-12 pm)IR image sensor using a silicide/ p-Si, -,Ge, Schottky contact for the strained layer monolithically grown on a p-Si CCD substrate.

11 E0030 IR DETECTOR - FOCAL PLANE ARRAY - CHARGE COUPLED DEVICE (CCD)

IRCCD focal plane arrays are being produced both in monolithic technology, where the detector and CCD materials are inseparable; and in hybrid technology, where photodetection and charge generation take place in any one of the various IR photodetectors and charge transfer takes place in the standard silicon CCD. In the latter case the role of the CCD is signal processing, performing multiplexing, delay-and-add operations and amplification.
CCD's operate by storing information in the form of "packets of charge" in an array of closely-spaced capacitors. The information in the array can be manipulated by pulsing capacitors sequentially such that the charge packet is transferred from one to the next and so on. The IRCCD is a self-scanning semiconductor imaging device that utilizes MOS (metal-oxide-semiconductor) technology, surface storage and information transfer. It consists basically of a metal-insulator-semiconductor (MIS) capacitor, majority carriers being attracted to the semiconductor-insulator interface [illegible]

is applied to the metal. Reversal of the voltage polarity creates a region depleted of majority carriers, an empty potential well. Minority carrier charge representing information accumulates in the well, partially filling it. Information is transferred from one well to another.

The hybrid IRCCD category has two types, direct injection (where the photodetector is coupled directly to an input tap of the CCD without any signal conditioning) and the indirect injection approach (where a buffer stage is interposed between the two components to improve the signal characteristics prior to the shift register stage).

One type of monolithic IRCCD which uses four-phase extrinsic silicon, has low responsivity, is non-uniform, is noisy, and requires temperatures below 40 K. Another monolithic intrinsic device, the Pt/Si Schottky barrier IRCCD has high uniformity, uses conventional silicon wafers, has a low cost and high yield but it has poor detectivity (compared to HgCdTe), a quantum efficiency of less than 4%, requires cooling to lower than 80 K and has a fill factor of less than 50%. The monolithic HgCdTe technology has problems of poor passivation, low reproducibility and limited array size. The monolithic GaAs technology has low dark current and is promising for the visible region, but has not been fully developed.

Only monolithic intrinsic Si technology has produced large mosiac arrays (1000x1000) for the visible and near-infrared spectrum.

A key problem for IRCCD is that the uniformity of IR materials is poor and that the resulting nonuniformity in the responsivity of IR detectors is of the same order or even higher than the typical scene contrast, which severly degrades the minimum resolvable temperature and results in a severe fixed pattern noise.

Hybrid IRCCD's offer better promise because they involve the coupling of two fairly well developed technologies. The two methods for introducing the IR signals from the detector array to the CCD are either by direct coupling (direct injection) or by using a buffer interface between the two that provides signal conditioning, amplification, and AC coupling. InSb direct injection detectors have been developed for the 3 to 5 uM region and buffered HgCdTe detectors have been built for the 8 to 14 uM region.

117 E060A Fujitsu has produced an engineering model of an infrared charge-coupled device (IRCCD) operating at a wavelengthof 8 to 12 microns. Fujitsu, Toshiba, MitsubishiElectric, and NEC worked under contract to the Japanese Defense Agency for its development. The IRCCD providesclear image recognition with 16,400 picture elements atnormal and low temperatures. By next year Fujitsu plansto produce a detector cooled to -200 deg C which can detect objects with temperature differences of less than0.1 deg C. Applications in domestic high-performancepassive infrared missile guidance systems are expectedwithin three to four years.

50 E028A MUSE-A

The ISAS (Institute of Space and Astronautical Science)has started a new project, Muse-A, by the approval of theSpace Activities Commission.

MUSES is an acronym for Space Engineering Spacecraftlaunched by the Mu rocket which is a three stage solidrocket developed by ISAS.

MUSES-A is dedicated to a mission of double lunal swingbywhich is a mandatory technology to be mastered beforeGeotail, a joint US-Japan Program for ISTP (InternationalSolar Terrestrial Physics program). Besides the swingby,the MUSES-A spacecraft will carry a tiny satellite at-
acched to the top, and inject it into an orbit around themoon prior to the first lunar swingby.

Japanese planetary scientists regard the mission ofMUSES-A not only as a verification of Technology forGeotail, but also as a precursor for future scientificlunar exploration. Recent study carried out in a plantaryscientist group has brought a concept of a lunar probecarving penatrators and some remote sensing instruments.

57 E030A

ABSTRACT

An iridium silicide Schottky-barrier (IrSi SB) infrared image sensor with 512x512 pixels has been developed. The Charge Sweep Device architecture is applied to the device. The detector is an IrSi/p-Si SB aiode, which has a cutoff wavelength of 7.3pm. The device is cooled to 62K for reducing thermally generated dark current. The device operates at the NTSC frame rate (30 frames/s). The examples of thermal imaging with this device are demonstrated.

72 E044A NEC has developed an infrared charge-coupled device (CCD)image sensor with 160,000 picture elements. The sensorcan detect temperature differences of 0.1 deg C, and anelectronic shutter can film objects that move
quickly or change temperature rapidly, even in the dark.The length of a detectable wave is 3 to 5 microns. Thebump technique was used for silicon chip bonding,reducing the size of the package by 40 percent comparedwith those currently available.

120 E062B The optical sensor system (OPS) that will be carried on Earth Resouces Satellite-1 (ERS-1) will be equivalent to a high-performance eye which observes the Earth from space, and will obtain data which will be useful in investigating such resources as oil and minerals. We have now completed the engineering model (EM) that we have been developing as a large project of MITI, and delivered it to the satellite. This OPS obtains high-resolution images and stereoscopic images by dividing light of a wide range of wavelengths, from visible to short-wavelength infrared, into multiple bands. For this purpose it employs many new technologies, such as a wide-angle, high-resolution aspherical optical system and a 4,096 element CCD [charge coupled device].

The main features of the OPS are as follows:

I) Observation bands: 3 visible near infrared bands 0.52 to 0.86 micron); 1 stereoscopic vision band (0.76 to 0.86 micron) and wavelengths; 4 short-wavelength infrared bands (1.5 to 2.4 micron)

II. Field of observation: 75km

III. Surface resolving power: 18x24 m

At present we are designing and manufacturing a proto flight model (PFM) of the OPS which can actually be launched, incorporating the of the EM.

87 E0000 IR DETECTOR - VIDICON

This Vidicon is a simple infrared sensitive television camera tube in which a thin layer structure serves as a radiation sensor, signal output electr ode, and the image-charge storage member which is scanned by a beam of low-velocity electrons to develop a video signal.

The vidicon sensing layer is referred to as the retina and is modeled as an array of elemental capacitors, each corresponding to a small area of the layer. IR radiation in the image acts to charge the free surface more positively. Beam electrons are deposited on the free surface to erase this positive charge, constituting a video signal current.

The amount of charge deposited by the beam on each retina area (and hence the magnitude of the video signal from that area) is a function of the exposure of that area in the preceding frame time. As in all vidicons, the action of the electron beam is to erase the charge from each elemental retina area in turn as it returns that area essentially to cathode potential.

89 E054A INFRARED VIDICONS

A PbO-PbS photoconductive target makes these vidiconssensitive to a broad range of wavelengths up to 2200nm.
Normally they are used for infrared only, with a visiblecutoff filter.

Application:

* Nondestructive inspection of semiconductor materials.
* Inspection of VLSI curcuits
* Measurements of tranmission characteristics of quartz optical fibers
* Night surveillance
* Observation of historical documents and drawings
* Temperature measurements
* Observation of infred·light sources
* monitoring of furnaces

90 E054B INFRARED VIDICONS

PbO-PbS photoconductive target makes these vidiconssensitive to a broad range of wavelengths up to 2200nm. Normally they are used for infrared only, with a visible-cutoff filter.

Applications
* Nondestructive inspection of semiconductor materials *
Inspection of VLSI curcuits
* Measurement of transmission characteristics of quartz optical fibers
* Night surveillance *
Observation of historical documents and drawings
* Temperature measurement
* Observation of infrared light sources (lasers, LEDs, laser diodes, hydrogen flames, etc.) * Monitoring of furnaces

91 E054C SILICON VIDICONS

These vidicons use a silicon photodiode array as thephotosensitive surface. Responsive to a wide wavelengthrange from 380 to 1100nm, they can be used in boththe visible and infrared regions, and feature highsensitivity, low dark current, low lag, a light transfer gamma characteristic close to 1 , and noburn-in.

Applications

* Security and SUlveillance
* Remote sensing
* Industrial instrumentation
* Medical imaging
* Measurement of transmission characteristics of plastic optical fibers
* Observation of near infrared light sources (LEDs, laser diodes and lasers)

92 E054D SILICON VIDICONS

These vidicons use a silicon photo diode array as thephotosensitive surface. Responsive to a wide wavelengthrange from 380 to 1100nm, they can be used in both thevisible and infrared regions, and feature highsensitivity, low dark current, low lag, a light transfergamma characteristic close to 1, and no burn-in.

Applications

* Security and surveillance
* Remote sensing
* Industrial instrumentation
* Medical imaging
* Measurement of transmission characteristics of plastic optical fibers
* Observation of near infrared light sources (LEDs, laser diodes and lasers)

123 E065A A method of attitude determination of spacecraft by meansof an optical technique is presented in which the laserbeam is transmitted from a ground station and detected bya TV camera on a satellite. The principal of determiningthree attitude parameters using the sequential multiplespot images of the laser beam transmitter appearing inthe TV camera's image plane is discussed briefly.Experiments of attitude determination by this method havebeen conducted, where a TV camera on board the JapaneseEngineering Test Satellite-3 (ETS-3) and a ground-basedoptical station are used. In the experiments, argon lasertransmission from the earth to space and satelliteobservation by the optical system were donesimultaneously. The sttitude of the satellite wasdetermined with high accuracy for some orbits, whichpermitted us to evaluate the three axis attitude controlsystem and some attitude control experiments of thesatellite.

88 D033D VIDICON CAMERA - ENGINEERING TEST SATELLITE ETS-III

FLOWN - FY1982
PURPOSE - REMOTE SENSING
RESOLUTION - 400m
FOV - 15.9 deg x 12.0 deg
BAND:
CH1: 0.46-0.6 um
CH1: 0.6-0.7 um
CH1: 0.7 0.88 um
IMAGING DEVICE - CdSe VIDICON TOSHIBA
POWER - 700W

10 E0000 IR DETECTOR - CRYOGENIC COOLERS

IR imaging systems have a requirement for cryogenic (very low temperature) coolers which are used to cool the IR sensors. These coolers have established major restraints on the maintenance, reliability, configuration, noise, vibration, and power requirements of the system. The IR detector mission will play a large part in determining the cooler design. The probable range of performance extends from cooling HgCdTe to 77K in manportable systems up to cooling large silicon focal plane arrays to 45K and other ground applications to 170K to 220K. 273 deg K equals 32 deg F and 77 deg K is approximately -315 K. Four classes of coolers are of interest:

manportable systems
combat vehicle systems
aircraft based systems
spacecraft based systems

Each application has unique requirements which often dictate the design approach. Manportable units must be small, lightweight and quiet. Open-cycle, Joule Thomson coolers have been used (employing a compressed gas cartridge). Split Stirling units have also been used. The coolers in combat vehicles can be larger and heavier. Aircraft mounted sensors require greater accuracies and can tolerate less vibration transmitted from the cooler. Spacecraft based systems are even more sensitive to vibration and must have exceptional reliability and very long lives.

Technology	Type	Temp range Deg K	Capacity Watts
Joule_Thomson (JT) expansion	OC	4-87	mW to 20
Stirling -dual reciprocating design	ME	10-77	mW to 15
Vuilleumier (VM) (Split design)	ME	10-77	mW to 15
Thermoelectric (Peltier effect)	TH	230-300	.1-100
Adsorption	OC		
Brayton cycle (Turbo Brayton) (gas brg)	ME	4-77	10-100
Rotating Reciprocal Refrigerator	ME		
Dewar & stored cryogen (liquid)	OC	4-77	Unlimited
Dewar & solid cryogen	OC	8-150	1
Passive radiators (space environment)	RA	100-200	1-10 (1g)

Open cycle type (OC) coolers all utilize a stored coolant. A stored solid cryogen can provide reliable refrigeration of modest heat sources for 3 or more years, but solid and liquid cryogens require heavy, elaborate, well insulated storage bottles or containers. The JT cooler which uses the expansion of a high-pressure gas is simple and inexpensive although for high capacity applications, the gas bottle itself must be cooled. While good for intermittent operation over a long period of time, the limited capacity of the heavy storage bottle is a drawback.

While simple passive radiators (RA) are ideal for space applications, their size grows quickly for moderate heat loads. While mechanical (ME) coolers offer the highest capacity for their size and weight, so far none can operate for more than a few thousand hours without maintenance. The reversed-Brayton which is a rotary device uses gas-bearings and thus has potential for high reliability and very long life and is only limited by the number of start-stop cycles. They all require input power in the form of heat, electricity or rotary motion, and their mechanical operation (either rotation or reciprocating pistons)

can induce vibrations in the sensor being cooled, if not properly isolated.

Thermoelectric (TH) coolers provide simple, reliable, lightweight cooling for modest heat loads, but require electrical power and are limited by low efficiency. (Source:JAM/Pg 15-2 to 15-78)

37 E009D
81 E050A PERFORMANCE SPECIFICATIONS - STARLING COOLER

MISSION - ERS-1 SATELLITE DEVELOPED FOR SWIR
COOLING CAPACITY - 1.0W MIN.
COOLDOWN TIME - 10 MIN
INPUT VOLTAGE - 115V, 400Hz
POWER REQUIRED - 70W MAX
WEIGHT - 4.9kg
OPERATING TEMPERATURE - -20 DEG C - + 50 DEG C
STORAGE TEMPERATURE - -30 DEG C - + 60 DEG C

VIBRATION (NON-OPERATING) -	X-AXIS RANDOM 20 - 200Hz +6db/OCTAVE 200 - 500Hz 0.6g^2/Hz 500 - 2000Hz -12db/OCTAVE
	Y, Z-AXIS RANDOM 20 - 200 Hz +6db/OCTAVE 200 - 1500 Hz 0.2g^2/HZ 1500 - 2000 HZ -12db/OCT
IMPULSE NON-OPERATING	100 - 600 Hz +8db/OCT 600 - 3000Hz 200 G^2/Hz
FATIGUE TEST	X,Y,Z-AXIS RANDOM NO ACCIDENT FOR 12 MIN/EACH AXIS
MEAN LIFE TIME	3500 h

83 E051B Marine Observation Satellite (MOS-1)

In MOS-1, three types of imaging radiometers are installed: a visible and thermal inflared radiometer (VTIR) which takes pictures of the ocean, and clouds in one visible and three thermal infared bands and measures the temperature of the ocean or cloud tops; a multispectral electronic selfscanning radiometer (MESSR) for visible and near infrared bands forcartography; and a microwave scanning radiometer (MSR) for measuring sea surface temperature when it is cloudy.

Visible and Thermal Infrared Radiometer (VTIR)
The VTIR installed in MOS-1 has one visible band (wavelength = 0.5 0.7um) and three thermal infrared bands (wavelength = 6.0-7.0 um, 10.5-11.5 um, and 11.5-12.5 um). Images of clouds, water vapor and the temperature on the sea surface or cloud tops are obtained using this sensor.

The VTIR uses a rotating mirror scanner, a Ritchey-Chretien telescope (a reflecting optical system), radiatively cooled mercury cadmium tellununl (HgCdTe)

rated capacity of 5 W is the development goal. The confirmation of action of the Starling cycle is theobjective of the first BBM. NASDA already confirmed through basic experiments that a freezing capacity of 3W could be obtained under the conditions of maintaining 70K temperature for the sensor's mounting section. Based on this experiment, Hitachi, Ltd., plans to start the production of the second BBM in FY89.

Structurally, the Starling freezer has a heat storagematerial, through which a working liquid can pass, between two compartments whose volumes can be varied by a piston and a displacer, respectively. By driving the piston and the displacer, a freezing cycle is created by changingthe two compartment volumes as a certain phase gap. Toinsure a long space use life, both piston (43mm diameter x 8mmstroke) and displacer (20mm diameter x 3mm) are most uniquelymaintained with magnetic bearings and driven by a linear motor tohave no contact with their casings.

Prior to the production of the first BBM, Hitachi, LTD., had confirmed separately the actions of the linear motor to drive the piston and displacer and the action of the magnetic bearings. Initially, the magnetic bearings were designed to control the on and off of the currentsthrough themselves, whenever a radial displacement was detected. Subsequently, however, the control mechanism was changedto a propotion, integration and differentiation (PID) type, which was capable of more precise control, in order to totally prevent contacts with the casing.

The first BBM was designed without considering the viscosity of helium. However, the effects of the viscosity were so unexpectedly significant in action experiments that the pressure of helium, which was used to brake the moving piston, was off a calculated value. Also learned from these experiments was the need toconsider the effects of heat evolved by induction losses caused by the linear motor and the magnetic bearings in the pistonand the displacer. Hitachi, Ltd., plans to reflect theseresults in the design of the second BBM.

18 E003C A cooled infra-red telescope (IRTS) is planned to be launched in 1993, which will be accommodated to the Space Flyer Unit (SFU). It is cooled down to 1.8K by 100 dm^3 of stored supefluid helium, being capable of photometric observation even in sub-millimetre regions. The cooled mission lifetime is required to be longer than several weeks. Minimization of heat leak to the lowest temperature level is one of the primary design goals for maximum life time. The liquid cryogen management in the zero-g situation is another key item. The ground operation at the launching site should also be well planned, especially in liquid helium treatment

A number of requirements and limitations, which can be hardley compromised with each other, have been taken into account during the conceptual design phase. The observation plan inevitably requests cryogenic cooling of the telescope and the Focal Plane Instruments (FPI). It is anticipated that a He refigerator will be employed to cool the FIRP down to 0.25K. The observation period, at least for several weeks, is an essential prequisite for significant sky coveraage

infrared detectors, and silicon PIN diode.Theinstantaneous field of view (IFOV) on the earth is 900 m for the visible band and 2700m for infrared bands, and the scan width is about 1500km.

The scanning radiometer consists of a scan mirror, its driving motor, a black-body raditor for reference, focusing mirror, filters, relay lenses and detectors mounted on the radiation cooler.

Infrared radiation from the target is conducted to the cooled mercury cadmium tellunum (HgCdTe) detector. Visible light is directly conducted to a silicon PIN diode from the focusing mirror.

Radiation cooler (RC) has the function to cool down the detector temperature by thermal energy radiation into space. The RC temperature is balanced, when the energy input to the detectors is equal to the thermal energy radiated from them. Detectors are then cooled to an ultralow temperature (about 115 K) for operation.

Infrared detectors are mounted on the RC, which is cooled to about 115K. The VTIR's RC has two stages: the stage-1 temperature is about 150K, and that for stage-2 is about 115 K.

The sensor observes the earth when the mirror faces in that direction and calibrates to the reference black-body when the mirror faces it.

Electrical signals from the detectors are amplified, converted to digital, and multiplexed for transmission.

56 E029E PbSe DETECTORS

BT2 PbSe DETECTORS MOUNTED ON TWO STAGE THERMOELECTRICCOOLERS AND PACKAGED IN EITHER TO-5 OR TO-8 CANS. THESEDETECTORS OFFER AN ECONOMICAL CHIOCE WITH EXTREMELY HIGHSENSITIVITY IN THE 1 TO 5 MICRON SPECTRAL REGION ANDCOMPARES WITH DEVICES OPERATING AT 77 DEGREES K WITHOUTTHE INCONVIENCE OF THE LIQUID COOLING.

62 E032C THERMOELECTRIC COOLER

DETECTOR TEMPERATURE	0 DEG. C
TEMPERATURE SETTING ACCURACY	WITHIN 1 C
OUTPUT CURRENT FOR TEMPERATURE CONTROL	2 A MAX
AMBIENT TEMPERATURE (OPERATING)	+10 DEG C + 10 DEG. C
AMBIENT HUMIDITY (OPERATING)	LESS THAN 90%
LINE VOLTAGE	AC100V
POWER CONSUMPTION	APPROX. 30VA

70 D025A Research Space Freezer Model by Hitachi

Hitachi, Ltd., a recipient of the FY87 order from the National Space Development Agency of Japan (NASDA) for a freezer for space uses, produced the first research model (BBM) of the freezer using the Starling cycle.

The space freezer has been under development for even-ual applications for cooling an infrared sensor for each observation, which is under development by Mitsubishi Electric Co. on consignment from NASDA, and as a multi-purpose freezer for space machines and devices. Helium is used as the working fluid for the freezer, and an 8,000-hours life under continuous operation at a

VISSR CHARACTERISTICS

Function --- Provide Visible & Infrared spectrum mapping of earth & cloud cover

	Visible Channels	Infrared Channels
Field Of View	35 x 31 urad	140 x 140 urad
Band	0.50 to 0.75u	10.5 to 12.5 u
Resolution	1.25km	5.0 km
Scanning Lines	2500 x 4	2500
Scan Step repeat	+-1.8urad	+-1.8 urad
Noise Performance	S/N>=45 alb=100%	NE T<+0.5K 300K
	S/N>=6.5 alb=2.5%	NE T<+1.5K 220K

47 E027C VTIR COOLER

THE VTIR MOUNTS A RADIATION COOLER TO COOL THE IRDETECTOR TO ABOUT 110K TO OBTAIN NECESSARY PERFORMANCE,WHICH IS EXPOSED TO SPACE. THE RADIATION COOLER IS IN ASPACE ENVIRONMENT WITH A PASSIVE COOLER.

121 E063A DEVELOPMENT OF MECHANICAL COOLLER FOR SPACE OBSEVATIONS

1. Institute of Space And Astronautical Science
   * H. Okuda
   * N.Tanatsuga
2. Nagoya University - T. Matsumoto
3. Nihon University - Y. Matsubara
4. Toyama Universtiy - H. Nagano
5. Tokyo Insitute of Technology - T. Hasimoto
6. Tsukuba University - M. Murakami
7. Nobeyama Radio Observatory - J. Inatani

Cryogenical cooling has become a crucial technique for modern astronomical observations in space. In particular,it is inevitable in infrared observations because,otherwise, the observations are fatally disturbed byextremely strong thermal radiation predominantly emittedin infrared region peaking near 10 microns.

In the past and presently planning missions, cryogencoolant has been used for the cooling of the instruments,where quite a large amount of coolant is necessary to warrant a certain life time of the mission. For keepingaway the environmental heat from the coolant, a bulky and heavy vacuum cryostat should be prepared.

Here, we propose development of mechanical coolers to replace the cryogen cryostats. Success of the developmentwill lead to substantial reduction of scale and weight ofthe instruments; we no more need a bulky and heavy vacuumchamber for the cryostat and hence a larger telescopewould be easier to be built within the severe limitationin size and weight, which is always requested in spaceexperiments. The development will be undertaken in the collaboration of scientists and experts in relevant engineering.

themselves, whenever a radial displacement was detected. Subsequently, however, the control mechanism was changedto a propotion, integration and differentiation (PID) type, which was capable of more precise control, in order to totally prevent contacts with the casing.

The first BBM was designed without considering the viscosity of helium. However, the effects of the viscosity were so unexpectedly significant in action experiments that the pressure of helium, which was used to brake the moving piston, was off a calculated value. Also learned from these experiments was the need toconsider the effects of heat evolved by induction losses caused by the linear motor and the magnetic bearings in the pistonand the displacer. Hitachi, Ltd., plans to reflect theseresults in the design of the second BBM.

64 E033B GMS-3 is a spin-stabilized geostationary meteorological satellite with mechanical despun antennas. GMSS-3 will be thde GMS-2 protoflight spacecraft refurbished to provide more capability and modified to improve its reliability. Hence, the configuration and characteristics of the spacecraft are improved over those of the predecessor, GMSS-2 and most subsystems are night-proven.

The spinning section includes VISSR and supporting subsystems. The forward assembly consists of VISSR, magnesium thrust tube, honeycomb equipment shelf, electronics, batteries, main wire harness, Reaction Control Subsystem (RCS) tanks and thrusters, solar panel, and thermal barriers. The aft assembly includes an Apogee Kick Motor (AKM), wire harness, AKM adapter, and separation hardware. The aft assembly is jettisoned after motor burnout.

The satellite mission life is 4--5 years due to the limited amount of on-board hydrazine fuel; however, the design life is 5 years. Redundancy of mission-critical functions is provided to ensure electronics lifetimes significantly in excess of 5 years. The solar panel power of 263 W includes an approximately 16W margin at the end of 5 years (summer solstice)

VISSR

The Visible and Infrared Spin Scan Radiometer (VISSR) is used to obtain visible and infrared spectrum mappings of the earth and its cloud cover with specially designed optical telescopes and detector system. A complete 20 x 20 degree scan of the full earth disk can be accomplished every 30 minutes utilizing the spacecrafts 100 rpm spin motion for east-west scans. Primary scanning requires 25 minutes, mirror retrace 2.5 minutes, and spacecraft stabilization another 2.5 minutes.

Using its scan, primary, and secondary mirrors, the optical telescope collects visible and infrared energy from images of the earth's surface and brings these images into focus at the focal plane. Visible fiber optics and infrared relay optics reley images from the telescope focal plane to redundant visible and infrared detectors. Photomultiplier Tubes (PMT) detectors convert visible light into visible analog signals, and HgCdTe detectors, cooled by a radiation cooler, converts the earth's radiation into infrared analog signal. The VISSR outputs are feed to VISSR Digital Multiplexer (VDM) unit., which is internally redundant, for processing.

in the scanning mode. Accommodation to the SFU imposes several strict limitations as well as an obvious advantage, or a possibility of reflight. The orbit and launching time must be seen as a type of given conditions. A minimum attitude control should be permitted in order to meet the requirement of the Sun and Earth avoidance angles as. Limitations of allowable size, maximum 1.05m in diameter and weight under 200kg, have great impact on the basic design of the IRTS.

Parameters For Thermal Analysis

HeII Tank Capacity	100I
Baffle	Reflective Type
Heat Input From Aperature	Case A 200mW AVG Case B 21mW MIN
Heat Dissipation In FPI	FIRP Peak 8.75 mW FIRP av. 4.25mW
Conduction Of FPI Through Wires	Dia.0.2mm X 135 Wires Material: Manganin
Support Straps	Alumina-FRP
Dewar Exit Cables	Signal:0.1 mm Dia.x 56 Drive: 0.5mm Dia. x 22 Material: Manganin
Temperature Of Outer Shell	300 K

71 D025A Research Space Freezer Model by Hitachi

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SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX F

X-RAY LITHOGRAPHY (XRL)

0701050A02 - XRL - SYSTEM PERFORMANCE

0701050B02 - X-RAY RADIATION SOURCES

0701050C02 - SHEET A - X-RAY MASKS

0701050C02 - SHEET B - X-RAY RESISTS

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TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: X-RAY LITHOGRAPHY

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** *** SUB-TECHNOLOGY: X-RAY LITHOGRAPHY SYSTEMS								
07010 50A02	A	BL		B	F0000		Y	
07010 50A02	A	JA	A	P	F017A	P	Y	ELECTROTACHNICAL LABORATORY
07010 50A02	A	JA	A	P	F001B	P	Y	ELECTROTECHNICAL LABORATORY OF THE AGENCY OF INDUSTRIAL SCIENCE AND TRADE
07010 50A02	A	JA	A	P	F026A	P	Y	HITACHI LTD, CENTRAL RESEARCH LABORATORY
07010 50A02	A	JA	E	P	F014C	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
07010 50A02	A	JA	A	P	F034A	P	N	MATSUSHITA ELECTRICAL INDUSTRIAL CO., LTD.
07010 50A02	A	JA	A	P	F007A	P	N	NEC CORPORATION
07010 50A02	A	JA	A	P	F016A	P	Y	NEC CORPORATION
07010 50A02	A	JA	A	P	F018A	P	Y	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORIES
07010 50A02	A	JA	A	P	F013A	P	Y	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORY
07010 50A02	A	JA	E	P	F003A	P	Y	OSAKA UNIVERSITY, LASER NUCLEAR FUSION RESEARCH CENTER
07010 50A02	A	JA	E	P	F022A	P	Y	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50A02	A	JA	C	P	F029B	P	Y	SORTEC CORPORATION

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07010 50A02	A	JA	A	P	F008A	P	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD, OSAKA RESEARCH LABORATORY
** *** SUB-TECHNOLOGY: X-RAY RADIATION SOURCES								
07010 50B02	A	BL		B	F000		Y	
07010 50B02	A	JA	E	P	F028A	P	Y	
07010 50B02	A	JA	E	P	F031B	P	Y	
07010 50B02	A	JA	E	P	F009A	P	Y	CANON CENTRAL RESEARCH LABORATORY
07010 50B02	A	JA	E	P	F017B	P	Y	ELECTROTECHNICAL LABORATORY
07010 50B02	A	JA	E	P	F016B	P	N	ELECTROTECHNICAL LABORATORY
07010 50B02	A	JA	E	P	F032B	P	Y	ELECTROTECHNICAL LABORATORY
07010 50B02	A	JA	E	S	F001A	F016B	Y	ELECTROTECHNICAL LABORATORY OF THE AGENCY OF INDUSTRIAL SCIENCE & TECHNOLOGY
07010 50B02	A	JA	E	S	F016E	F017B	N	ELETROTECHNICAL LABORATORY
07010 50B02	A	JA	E	S	F002B	F002A	Y	HITACHI LTD.
07010 50B02	A	JA	E	P	F021B	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
07010 50B02	A	JA	E	P	F026B	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
07010 50B02	A	JA	E	P	F032D	P	Y	ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES

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TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
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SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
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07010 50B02	A	JA	E	P	F005A	P	Y	JAPAN ATOMIC ENERGY RESEARCH INSTITUTE
07010 50B02	A	JA	B	P	F033A	P	Y	MITSUBISHI ELECTRIC CORPORATION, LSI RESEARCH CENTER
07010 50B02	A	JA	E	P	F004A	P	Y	MITI
07010 50B02	A	JA	E	P	F032F	P	Y	MITSUBISHI ELECTRIC, CENTRAL RESEARCH LABORATORY
07010 50B02	A	JA	E	P	F016D	P	N	NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F032G	P	Y	NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F002A	P	Y	NATIONAL LABORATORY OF HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	S	F016H	F032G	N	NEC CORPORATION
07010 50B02	A	JA	E	S	F018B	F032G	Y	NEC CORPORATION, MICROELECTRONICS RESEARCH LABOARTORIES
07010 50B02	A	JA	E	S	F012A	F032G	Y	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORY
07010 50B02	A	JA	E	S	F027A	F032G	Y	NEC CORPORATION, MICROELECTRONICS RESEARCH LABS.
07010 50B02	A	JA	E	S	F013B	F032G	Y	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY
07010 50B02	A	JA	E	S	F010A	F032A	Y	NIPPON TELEGRAPH & TELEPHONE

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TECHNOLOGY: X-RAY LITHOGRAPHY

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
07010 50B02	A	JA	E	S	F016G	F032A	N	NIPPON TELEGRAPH & TELEPHONE
07010 50B02	A	JA	E	S	F006A	F032A	Y	NIPPON TELEGRAPH & TELEPHONE CORP. (NTT)
07010 50B02	A	JA	E	S	F030A	F032A	Y	NIPPON TELEGRAPH & TELEPHONE CORP. (NTT)
07010 50B02	A	JA	E	P	F032A	p	Y	NIPPON TELEGRAPH AND TELEPHONE
07010 50B02	A	JA	E	S	F009C	F032A	Y	NIPPON TELEPHONE & TELEGRAPH
07010 50B02	A	JA	E	S	F016F	F019B	N	PHOTON FACTORY
07010 50B02	A	JA	E	P	F019A	P	Y	PHOTON FACTORY, NATIOANAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F019B	P	Y	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F019C	P	Y	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F019D	P	Y	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F019E	P	Y	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	S	F022B	F019C	Y	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS
07010 50B02	A	JA	E	P	F011B	P	Y	SEE MEMO FIELD FOR PARTICIPANTS

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
07010 50B02	A	JA	E	P	F032E	P	Y	SORTEC
07010 50B02	A	JA	E	S	F029A	F032E	Y	SORTEC CORPORATION
07010 50B02	A	JA	C	S	F015A	F032B	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORIES
07010 50B02	A	JA	C	S	F008B	F032B	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORY
07010 50B02	A	JA	E	S	F011A	F032C	Y	SUMITOMO HEAVY INDUSTRIES
07010 50B02	A	JA	E	P	F032C	P	Y	SUMITOMO HEAVY INDUSTRIES
07010 50B02	A	JA	E	S	F016C	F032C	N	SUMITOMO HEAVY INDUSTRIES LTD.
07010 50B02	A	JA	E	S	F031A	F032C	Y	SUMITOMO HEAVY INDUSTRIES, LTD.
07010 50B02	A	JA	C	S	F009B	F032C	Y	SUMITOMO HEAVY METALS
07010 50B02	A	JA	E	P	F023A	P	Y	TOHOHU UNIVERSITY

** *** SUB-TECHNOLOGY: X-RAY MASKS

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
07010 50C02	A	BL		B	F0000		Y	
07010 50C02	A	JA	E	P	F016I	P	N	DAI NIPPON PRINTING CO., LTD.
07010 50C02	A	JA	E	P	F014B	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
07010 50C02	A	JA	E	P	F016K	P	N	HOYA CORPORATION

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
07010 50C02	A	JA	B	P	F033B	P	Y	MISUBISHI ELECTRIC CORPORATION, LSI RESEARCH CENTER
07010 50C02	A	JA	B	P	F025A	P	Y	MITSUBISHI ELECTRIC CORPORATION, LSI RESEARCH & DEVELOPMENT LABORATORY
07010 50C02	A	JA	E	P	F013C	P	Y	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY
07010 50C02	A	JA	E	P	F020A	P	Y	SANYO ELECTRIC COMPANY, TSUKUBA RESEARCH CENTER
07010 50C02	A	JA	E	P	F008D	P	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORY
07010 50C02	A	JA	E	P	F016J	P	N	TOPPAN PRINTING CO., LTD.
07010 50C02	A	JA	E	P	F024A	P	Y	TOPPAN PRINTING COMPANY
** *** SUB-TECHNOLOGY: X-RAY RESISTS								
07010 50C02	B	BL		B	F0000		Y	
07010 50C02	B	JA	A	P	F014A	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
07010 50C02	B	JA	E	P	F021A	P	Y	HITACHI, LTD., CENTRAL RESEARCH LABORATORY
07010 50C02	B	JA	D	P	F032C	P	Y	JAPAN SYNTHETIC RUBBER CO.
07010 50C02	B	JA	C	P	F016L	P	Y	NEC CORPORATION
07010 50C02	B	JA	B	P	F020B	P	Y	SANYO ELECTRIC CO., LTD., TSUKUBA RESEARCH CENTER

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
07010 50C02	B	JA	D	P	F008C	P	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORY

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: X-RAY LITHOGRAPHY

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: X-RAY LITHOGRAPHY SYSTEMS							
07010 50A02 A XRL	RESOLUTION --- MICRONS (um) --- IMPR. DIR: L	THROUGHPUT --- WAFERS/HOUR (150mm DIA) --- IMPR. DIR: H	REGISTRATION PRECISION --- MICRONS (um) --- IMPR. DIR: L	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF
** ******************** SUB-TECHNOLOGY: X-RAY RADIATION SOURCES							
07010 50B02 A XRL	POWER LEVEL --- KILOWATTS (kW) --- IMPR. DIR: H	PROJECTED SPOT SIZE --- MILLIMETER (mm) --- IMPR. DIR: L	POWER DENSITY --- kW/cm^2 --- IMPR. DIR: H	TECHNOLOGY TYPE --- NONE --- IMPR. DIR: X	--- --- IMPR. DIR:	--- --- IMPR. DIR:	FAC
** ******************** SUB-TECHNOLOGY: X-RAY MASKS							
07010 50C02 A XRL	FLATNESS --- MICRONS (um) --- IMPR. DIR: L	RELATIVE DISTORTION (MASK TO MASK) --- MICRONS (um) --- IMPR. DIR: L	DEFECT DENSITY --- Q/CM^-2 --- IMPR. DIR: L	DEFECT SIZE (MAX) --- MICRONS (um) --- IMPR. DIR: L	LIFETIME (SHOTS) --- QTY @ 1mW/cm^2 FLUX --- IMPR. DIR: H	TECHNOLOGY (MATERIAL) --- NONE --- IMPR. DIR: X	MATL
** ******************** SUB-TECHNOLOGY: X-RAY RESISTS							
07010 50C02 B XRL	SENSITIVITY --- mJ/CM^2 --- IMPR. DIR: L	RESOLUTION --- MICRONS (um) --- IMPR. DIR: L	TECHNOLOGY NAME --- NONE --- IMPR. DIR: X	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	MATL

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TECHNOLOGY: X-RAY LITHOGRAPHY

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: X-RAY LITHOGRAPHY SYSTEMS												
07010 50A02 A XRL 44	A	ELECTROTACHNICAL LABORATORY ---- UMEZONO, TSUKUBA-SHI, IBARAKI-KEN 305, JAPAN ---- J.ITOH, T.KANAYAMA, N.ATODA & K.HOH ----	---- ---- ----	---- ---- ----	Y A DT U	0.25 ----	----	----	----	----	----	JBL/VOL 60 #7/0163 8 07/01/8 9 F017A / / JA
07010 50A02 A XRL 6	A	ELECTROTECHNICAL LABORATORY OF THE AGENCY OF INDUSTRIAL SCIENCE AND TRADE ---- 1-2, NAMIKI, TSUKUBA, IBARKI PREF. 305, JAPAN ---- ----	SUMITOMO ELECTRIC INDUSTRIES, LTD. ---- 1-3, SHIMAYA 1-CHOME, KONOHANA-KU, OSAKA 554, JAPAN ---- ----	---- ---- ----	Y P DT U	>0.25 ---- SEE MEMO	----	----	----	----	----	JDQ/07-09-87/0 52 07/09/8 7 F001B 10/01/8 8 JA
07010 50A02 A XRL 62	A	HITACHI LTD, CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- Y.KATO, I.ICHIAI, Y.WATANABE, S.MURAYAMA ----	---- ---- ----	---- ---- ----	Y A DT U	0.4 ---- SEE MEMO	----	----	----	----	----	JDY/VOL 6 #1/0195 02/01/8 8 F026A / / JA
07010 50A02 A XRL 30	E	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- K.MOCHIJI, H.OIZUMI, Y.SOODA, T.OGAWA ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JDY/VOL 60 # 6/02158 10/01/8 8 F014C / / JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50A02 A XRL 81	A	MATSUSHITA ELECTRICAL INDUSTRIAL CO., LTD. ---- 1006, KADOMA OAZA KADOMA, OSAKA 571 JAPAN ---- ---- THIS INFORMATION WAS CONTAINED IN TWO SEPERATE ARTCLES ON THE SAME PAGE.	SORTEC CORPORATION ---- TSUKUBA, IBARAKI PREFECTURE, JAPAN ---- ----	---- ---- ----	N A DT U	0.25 ---- AT SORTEC S LABORA TORY	----	0.075 ----	----	----	----	JAY/VOL 28 #1401/0 15 02/10/9 0 F034A / / JA
07010 50A02 A XRL 13	A	NEC CORPORATION ---- NEC BLDG., 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	0.2 ----	040 ---- 25x25M M AREAS	----	----	----	----	JDQ/10- 29-87/0 34 10/29/8 7 F007A 10/29/8 7 JA
07010 50A02 A XRL 32	A	NEC CORPORATION ---- NEC BLDG, 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- K.OKADA ----	---- ---- ----	---- ---- ----	Y P RD U	0.1 ----	---- HIGH	----	----	----	----	JAJ/10- 20-89/0 58 10/20/8 9 F016A / / JA
07010 50AC2 A XRL 46	A	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORIES ---- 1-1, MIYAZAKI YONCHOME, MIYAMAE-KU, KAWASKI 213, JAPAN ---- K.OKADA, E.NOMURA, K.SUZUKI & K.FUJII ----	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 1-1, MIYAZAKI YONCHOME, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- E.KOUNO, T.TANAKA & J.IWATA ----	NEC CORPORATION, RESEARCH & DEVELOPMENT PLANNING & TECHNICAL SERVICES DIVISION ---- 1-1, MIYAZAKI YONCHOME, MIYAMAE-KU, KAWASKI 213, JAPAN ---- Y.KAWASE ----	Y A DT U	0.25 ---- SEE MEMO	----	----	----	----	----	JBL/VOL 60 #7/0164 3 07/01/8 9 F018A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50A02 A XRL 25	A	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORY ---- 1-1, MIYAZAKI 4-CHOME, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- K.OKADA, K.SUZUKI, K.FUJII & E.NOMURA ----	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 484, TSUKAGOSHI 3-CHOME, SAIWA-KU, KAWASAKI 210, JAPAN ---- E.KOUNO, Y.TANAKA, J.IWATA, Y.TASAKI ----	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 484, TSUKAGOSHI 3-CHOME, SAIWA-KU, KAWASAKI 210, JAPAN ---- E.KAKIMOTO ----	Y A DT U	.2 ---- SEE MEMO	----	----	----	----	----	JDY/VOL 6 #6/0213 5 12/01/8 8 F013A 06/01/8 8 JA
07013 50A02 A XRL 9	E	OSAKA UNIVERSITY, LASER NUCLEAR FUSION RESEARCH CENTER ---- OSAKA, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JAU/MSG 2797-27 04/001 01/20/8 7 F003A / / JA
07010 50A02 A XRL 57	E	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- OHO, TSUKUBA-SHI, IBARAKI-KEN, 305, JAPAN ---- A.OGATA ----	THE UNIVERSITY OF TOKYO, RESEARCH CENTER FOR NUCLEAR SCIENCE & TECHNOLOGY ---- SHIRAKATA-SHIRANE, TOKAI-MURA, IBARAKI-KEN, 319-11, JAPAN ---- S.TAGAWA ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JBL/VOL 60 #7/0219 7 07/01/8 9 F022A / / JA
07010 50A02 A XRL 67	C	SORTEC CORPORATION ---- TSUKUBA, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P PP U	----	20-30 ----	----	----	----	----	JAY/VOL 27 #1394/0 16 12/16/8 9 F029B 03/01/9 0 JA

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07010 50A02 A XRL 14	A	SUMITOMO ELECTRIC INDUSTRIES, LTD, OSAKA RESEARCH LABORATORY ---- SHIMAYA, KONOHANA OSAKA 544, JAPAN ---- HIROSHI TAKADA & KOUHEI FURUKAWA ----	MINISTRY OF INTERNATIONAL TRADE & INDUSTRY AGENGY OF INDUSTRIAL SCIENCE & TECH. ---- SAKURA, NIIHARI IBARKI 305, JAPAN ---- TAKIO TOMIMASU ----	---- ---- ----	Y A DT U	0.25 ----	>=40 ----	----	----	----	----	JAS/VOL 27 # 7/0550 07/01/88 F008A / / JA

** ############### SUB-TECHNOLOGY: X-RAY RADIATION SOURCES

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50B02 A XRL 65	E	---- ---- SEE COMMENTS ---- SOUCE:FOREIGN BROADCAST INFORMATION - THIS ENTRY IS GENERAL INFOFMATION	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHRONTRON ----	----	----	JBE/SER-161100 26/01 11/26/89 F028A 08/01/89 JA
07010 50B02 A XRL 70	E	---- ---- ---- GENERAL INFORMATION SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYCHRONTRON ----	----	----	JBE/SER 1512124 189/01 12/15/89 F031B / / JA
07010 50B02 A XRL 18	E	CANON CENTRAL RESEARCH LABORATORY ---- ATSUGI, JAPAN ---- ---- REPORT OF VISIT TO CANON BY DR. CHARLES M. FALCO	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO FOR NARRATIVE	----	----	SYNCHROTRON ---- CANON IS DEVELOPING THE GRAZING INCIDENCE X-RAY EXPOSURE SYSTEM FOR	----	----	JAO/VOL 13 #4/034 12/01/88 F009A / / JA

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07010 50B02 A XRL 45	E	ELECTROTECHNICAL LABORATORY ---- UNEZOMO, TSUKUBA-SHI, IBARAKI-KEN 305, JAPAN ---- J.ITOH, T.KANAYAMA, N.ATODA & K.HOH ---- SOR-RING: TERAS	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	SYNCHRONTRON ----	----	----	JBL/VOL 60 # 7/01636 07/01/89 F017B / / JA
07010 50B02 A XRL 33	E	ELECTROTECHNICAL LABORATORY ---- UMEZONO, TSUKUBA, IBARAKI 305, JAPAN ---- ---- JOINT DEVELOPMENT WITH SUMITOMO ELECTRIC INDUTRIES	SUMITOMO ELETRIC INDUSTRIES ---- SHIYAMA, KONOHANA, OSAKA 554, JAPAN ---- ----	---- ---- ----	N A FP U	----	----	----	SYCHRONTRON ---- NAME - NIJI (RAINBOW)	----	----	JAJ/10-20-89/050 10/20/89 F016B / / JA
07010 50B02 A XRL 72	E	ELECTROTECHNICAL LABORATORY ---- ?, JAPAN ---- ---- SEE MEMO, PARTNERSHIP WITH ALL ORGANIZATIONS LISTED FOR NIJI I&II AND ONLY WITH SUMITOMO ON NIJI-III	SUMITOMO ELECTRIC INDUSTRY ---- 1-3, SHIMAYA 1-CHOME, KONOHANA-KU, OSAKA 554, JAPAN ---- ---- IN PATNERSHIP WITH ALL ORG. LISTED FOR NIJI I&II AND ONLY WITH ET LAB. FOR NIJI-III	MITSUBISHI ELECTRIC, TOSHIBA & SHIMADZU ---- JAPAN ---- ---- INVOLVED ONLY IN NIJI I & II	Y A FP U	---- SEE MEMO	----	----	SYNCHRONTRON ---- NIJI-I, NIJI-II, NIJI-III	----	----	JAJ/VOL 4 # 12/006 12/29/89 F032B 10/01/89 JA
07010 50B02 A XRL 56	E	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- K.MOCHIJI, Y.SOODA, M.ITO & T. KIMURA ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	SYNCHRONTRON ---- USED SYNCHRONTRON RADIATION FROM THE 2.5 GeV ELECTRON STORAGE RING AT THE NATION	----	----	JBL/VOL 60 #7/02160 07/01/89 F021B / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50B02 A XRL 63	E	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- Y.KATO, I.OCHIAI, Y.WATANABE, S.MURAYAMA ----	---- ---- ----	---- ---- ----	Y A DT U	----	SEE MEMO ----	SEE MEMO ----	PLASMA FOCUS ----	----	----	JDY/VOL 6 #1/0195 02/01/8 8 F026B / / JA
07010 50B02 A XRL 74	E	ISHIKAWAJIMA-HARIM A HEAVY INDUSTRIES ---- 2-1, OHTEMACHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYCHRO NTRON ---- LUNA	----	----	JAA/VOL 4 #12/006 12/29/8 9 F032D 08/01/8 9 JA
07010 50B02 A XRL 11	E	JAPAN ATOMIC ENERGY RESEARCH INSTITUTE ---- ?, JAPAN ---- ---- UNDER DEVELOPMENT	---- ---- ----	---- ---- ----	Y P TT U	---- SEE MEMO	----	----	SYNCHR OTRON ----	----	----	JAK/VOL 8 #29/045 02/01/8 9 F005A 01/01/9 0 JA
07010 50B02 A XRL 78	B	MITSUBISHI ELECTRIC CORPORATION, LSI RESEARCH CENTER ---- ?, JAPAN ---- N.YOSHIOKA & Y. WANTANABE ---- ARTICLE REFERRED TO THE USAGE OF A SX-5 X-RAY STEPPER MADE BY NIKON	NIKON ---- ?, JAPAN ---- K.KODAMA & H. IZAWA ----	---- ---- ----	Y A FP U	10 ----	3 ----	----	SYNCHR ONTRON ----	----	----	JAJ/01-02-90/0 14 01/02/9 0 F033A / / JA

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TECHNOLOGY: X-RAY LITHOGRAPHY

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50B02 A XRL 10	E	MITI ---- ---- ----	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JAA/VOL 3 #6/006 06/30/8 8 F004A / / JA
07010 50B02 A XRL 76	E	MITSUBISHI ELECTRIC, CENTRAL RESEARCH LABORATORY ---- ?, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	SYNCHR OTRON ----	----	----	JAA/VOL 4 #12/006 12/29/8 9 F032F / / JA
07010 50B02 A XRL 35	E	NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- OHO, TSUKUBA, IBARAKI 305, JAPAN ---- ---- JOINT DEVELOPMENT WITH FURUKAWA ELECTRIC CO.	FURUKAWA ELECTRIC CO. ---- 6-1, MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	N P RD	----	----	----	SYNCHR ONTRON ----	----	----	JAJ/10- 20-89/0 50 10/20/8 9 F016D / / JA
07010 50B02 A XRL 77	E	NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- ?, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYCHRO TRON ---- PHOTON FACTOR Y	----	----	JAA/VOL 4 #12/006 12/29/8 9 F032G / / JA

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07010 50B02 A XRL 7	E	NATIONAL LABORATORY OF HIGH ENERGY PHYSICS ---- TSUKUBA, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR ONTRON ----	----	----	JAK/VOL 7 #27/007 09/01/8 8 F002A / / JA
07010 50B02 A XRL 71	E	NIPPON TELEGRAPH AND TELEPHONE ---- ?, JAPAN ---- ---- SEE MEMO FOR DETAILS ON TWO SOR RINGS	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYCHRO NTRON ---- NTT-1 & SUPER-ALIS	----	----	JAA/VOL 4 #12/006 12/29/8 9 F032A 02/01/8 9 JA
07010 50B02 A XRL 48	E	PHOTON FACTORY, NATIOANAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI-KEN 305, JAPAN ---- H.KOBAYAKAWA & K.HUKE ---- WORLDWIDE CENCUS OF SOR'S	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	SYNCHR ONTRON ---- SEE MEMO	----	----	JBL/VOL 60 #7/0254 8 07/01/8 9 F019A / / JA
07010 50B02 A XRL 49	E	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI-KEN, 305, JAPAN ---- H.KOBAYAKAWA & K.HUKE ---- DATA SUPPLIED BY K.HUKE AUG.88	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	SYNCHR ONTRON ---- SEE MEMO	----	----	JBL/VOL 60 #7/0255 4 07/01/8 9 F019B 03/01/8 2 JA

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07010 50B02 A XRL 50	E	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI-KEN 305, JAPAN ---- H.KOBAYAKAWA & K.HUKE ---- DATA SUPPLIED BY M.ANDO & S.KAMATA	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYCHRO NTRON ---- TRISTA N AR	----	----	JBL/VOL 60 #7/0255 4 07/01/8 9 F019C / / JA
07010 50B02 A XRL 51	E	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI-KEN 305, JAPAN ---- H.KOBAYAKAWA & K.HUKE ---- DATA SUPPLIED BY T.ISHII AUG 88	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYNCHR ONTRON ---- sor ring	----	----	JBL/VOL 60 #7/0255 5 07/01/8 9 F019D 12/01/7 4 JA
07010 50B02 A XRL 52	E	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI-KEN 305, JAPAN ---- H.KOBAYAKAWA & K.HUKE ---- DATA SUPPLIED BY MAKATO WATANABE JULY 88	INSTITUTE FOR MOLECULAR SCIENCE ---- MYODAIJI, OKAZAKI 444, JAPAN ---- ---- SPONSOR	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYNCHR ONTRON ---- UVSOR	----	----	JBL/VOL 60 #7/0255 5 07/01/8 9 F019E 12/01/8 3 JA

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07010 50B02 A XRL 23	E	SEE MEMO FIELD FOR PARTICIPANTS ---- ---- ---- THIS ENTRY NAMES THOSE JAPANESE COMPANIES INVOLVED IN THE DEVELOPMENT OF SYNCHRONTRONS	---- ---- ----	---- ---- ----	Y A PE U	----	----	----	SYNCHR ONTRON ---- SEE MEMO	----	----	JDQ/07-09-87/0 52 07/09/8 7 F011B / / JA
07010 50B02 A XRL 75	E	SORTEC ---- TSUKUBA, JAPAN ---- ---- SEE MEMO	ELECTROTECHNICAL LABORATORY ---- TSUKUBA, JAPAN ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYCHRO TRON ---- SORTEC -1	----	----	JAA/VOL 4 #12/006 12/29/8 9 F032E 08/01/8 9 JA
07010 50B02 A XRL 73	E	SUMITOMO HEAVY INDUSTRIES ---- 2-1, OHTEMACHI, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYNCRO NTRON ---- AURORA	----	----	JAA/ VOL 4 #12/010 12/29/8 9 F032C 08/01/8 9 JA
07010 50B02 A XRL 59	E	TOHOHU UNIVERSITY ---- MIYAGAI-KEN, JAPAN ---- TOSHIHARU NAKAZATO ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR ONTRON ----	----	----	JBE/0W0 9101023 89/02 10/08/8 9 F023A / / JA

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** ############## SUB-TECHNOLOGY: X-RAY MASKS												
07010 50C02 A XRL 40	E	DAI NIPPON PRINTING CO., LTD. ---- ?, JAPAN ---- ---- ENTRY TO INDICATE PARTICIPATION IN MASK PRODUCTION	---- ---- ----	---- ---- ----	N A FP U	---- SEE COMMEN TS	----	----	----	----	----	JAJ/10-20-89/0 57 10/20/8 9 F016I / / JA
07010 50C02 A XRL 29	E	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- K.MOCHIJI, H.OIZUMI, Y.SOODA, T.OGAWA ---- ADDITIONAL RESEARCHER: T. KIMURA	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	BnP ----	JDY/VOL 60 # 6/02158 12/01/8 8 F014B / / JA
07010 50C02 A XRL 42	E	HOYA CORPORATION ---- , JAPAN ---- ---- ENTRY INDICATING PARTICIPATION IN MASK PRODUCTION	---- ---- ----	---- ---- ----	N A FP U	---- SEE COMMEN TS	----	----	----	----	----	JAJ/10-20-89/0 57 10/20/8 9 F016K / / JA
07010 50C02 A XRL 79	B	MISUBISHI ELECTRIC CORPORATION, LSI RESEARCH CENTER ---- ?, JAPAN ---- N.YOSHIOKA & Y. WATAKABE ---- USED FOR TEST MANUFACTURING 1M DRAM	NIKON ---- ?, JAPAN ---- K. KODAMA & H.IZAWA ----	---- ---- ----	Y A FP U	----	0.1 ----	----	----	----	SiN ----	JAJ/01-02-90/0 15 01/02/9 0 F033B / / JA

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07010 50C02 A XRL 61	B	MITSUBISHI ELECTRIC CORPORATION, LSI RESEARCH & DEVELOPMENT LABORATORY ---- 4-1, MIZUHARA, ITMAI 664, JAPAN ---- S.TAKEUCHI, K.MORIIZUMI, K.SAITO ----	MITSUBISHI ELECTRIC CORPORATION, LSI RESEARCH & DEVELOPMENT LABORATORY ---- 4-1, MIZUHARA, ITAMI, 664, JAPAN ---- N.YOSHICKA & T.KATA ----	---- ---- ----	Y A DT U	----	----	----	0.3 ----	----	SiN ----	JDY/VOL 60 #1/0146 02/01/8 8 F025A / / JA
07010 50C02 A XRL 27	E	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 484 TSUKAGOSHI 3-CHOME, SAIWA-KU, KAWASAKI 210, JAPAN ---- E.KOUNO, Y.TANAKA, J.IWATA, Y.TASAKI, ----	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 484 TSUKAGOSHI 3-CHOME, SAIWA-KU, KAWASAKI 210, JAPAN ---- E.KAKIMOTO ----	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORIES ---- 1-1, MIYAZAKI 4-CHOME, MYYAMAE-KU, KAWASAKI 213, JAPAN ---- K.OKADA, K.SUZUKI, K.FUJII, E. NOMURA ----	Y A DT U	---- SEE MEMO	----	----	----	----	SiN ----	JDY/VOL 6 #6/0213 5 12/01/8 8 F013C 06/01/8 8 JA
07010 50C02 A XRL 53	E	SANYO ELECTRIC COMPANY, TSUKUBA RESEARCH CENTER ---- KOYADAI, TSUKUBA, IBARAKI 305, JAPAN ---- J.NISHIRO, M.MORIGAMI, M.HARADA, T.GOTO ---- ADDITIONAL RESEARCHERS: S.TERAKADO, S.KOBAYASHI, S.FUJIWARA, K.KANEDA, R.SHIMIZU & S.SUZUKI	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- OHO, TSUKUBA, IBARAKI 305, JAPAN ---- H.MAEZAWA & M.ANDO ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	SiN ----	JBL/VOL 60 #7/0215 3 07/01/8 9 F020A / / JA

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07010 50C02 A XRL 17	E	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORY ---- SHIMAYA, KONOHANA OSAKA 554, JAPAN ---- HIROSHI TAKADA & KOUHEI FURUKAWA ----	MINISTRY OF INTERNATIONAL TRADE & INDUSTRY AGENCY OF INDUSTRIAL SCIENCE & TECH. ---- ELECTROTECHNICAL LABORATORY, SAKURA, NIIHARA IBARKI 305, JAPAN ---- TAKIO TOMIMASU ----	---- ---- ----	Y A DT U	----	----	----	----	----	Si3N3 ----	JAS/VOL 27 # 7/0550 07/01/8 8 F008D / / JA
07010 50C02 A XRL 41	E	TOPPAN PRINTING CO., LTD. ---- ?, JAPAN ---- ---- ENTRY INDICATING PARTICIPATION IN MASK PRODUCTION	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	----	----	JAJ/10-20-89/0 57 10/20/8 9 F016J / / JA
07010 50C02 A XRL 60	E	TOPPAN PRINTING COMPANY ---- SAITAMA PREFECTURE, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JAY/VOL 28 #1386/0 20 10/21/8 9 F024A / / JA
** *************** SUB-TECHNOLOGY: X-RAY RESISTS												
07010 50C02 B XRL 28	A	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- K.MOCHIJI, H.OIZUMI, Y.SOODA, T.OGAWA ---- ADDITIONAL RESEARCHER: T. KIMURA	---- ---- ----	---- ---- ----	Y A DT U	010 ----	0.3 ----	PPhMA ----	----	----	----	JDY/VOL 60 # 6/02158 10/01/8 8 F014A / / JA

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07010 50C02 B XRL 55	E	HITACHI, LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- K.MOCHIJI, Y.SOODA, M.ITO, T.KIMURA ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	PMPS ----	----	----	----	JBL/VOL 60 #7/0216 0 07/01/8 9 F021A / / JA
07010 50C02 B XRL 80	D	JAPAN SYNTHETIC RUBBER CO. ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	50 ----	----	----	----	----	----	JAJ/01-02-90/0 16 01/02/9 0 F032C / / JA
07010 50C02 B XRL 43	C	NEC CORPORATION ---- NEC BLDG, 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	<100 ----	0.1 ----	----	----	----	----	JAJ/10-20-89/0 57 10/20/8 9 F016L / / JA
07010 50C02 B XRL 54	B	SANYO ELECTRIC CO., LTD., TSUKUBA RESEARCH CENTER ---- KOYADAI, TSUKUBA, IBARAKI 305, JAPAN ---- J.NISHINO, M.MORIGAMI, M.HARADA, T.GOTO ---- ADDTIONAL RESEARCHERS: S.TERAKADO, S.KOBAYASHI, S.FUJIWARA, K.KANEDA, R.SHIMIZU & S. SUZUKI	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- OHO, TSUKUBA, IBARAKI 305, JAPAN ---- H.MAEZAWA & M.ANDO ----	---- ---- ----	Y A DT U	---- SEE MEMO	0.75 ----	EBR-9 ----	----	----	----	JBL/VOL 60 #7/0215 4 07/01/8 9 F020B / / JA

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07010 50C02 B XRL 16	D	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORY ---- SHIMAYA, KONOHANA OSAKA 554, JAPAN ---- HIROSHI TAKADA & KOUHEI FURUKAWA ----	MINISTRY OF INTERNATIONAL TRADE & INDUSTRY AGENCY OF INDUSTRIAL SCIENCE & TECH. ---- ELECTROTECHNICAL LABORATORY, SAKURA, NIIHARI IBARKI 305, JAPAN ---- TAKIO TOMIMASU ----	---- ---- ----	Y A DT U	0100 ----	0.25 ----	----	----	----	----	JAS/VOL 27 #7/0550 07/01/8 8 F008C / / JA

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** ############### SUB-TECHNOLOGY: X-RAY RADIATION SOURCES												
07010 50B02 A F016B XRL 5	E	ELECTROTECHNICAL LABORATORY OF THE AGENCY OF INDUSTRIAL SCIENCE & TECHNOLOGY ---- 1-2, NAMIKI, TSUKUBA, IBARAKI PREF. 305, JAPAN ---- ----	SUMITOMO ELECTRIC INDUSTRIES, LTD. ---- 1-3, SHIMAYA 1-CHOME, KONOHANA-KU, OSAKA 554, JAPAN ---- ----	---- ---- ----	Y P DT U	---- SEE MEMO	----	----	SYNCHR OTRON ----	----	----	JDQ/07-09-87/052 07/09/87 F001A 10/01/88 JA
07010 59B02 A F017B XRL 36	E	ELETROTECHNICAL LABORATORY ---- UMEZONO, TSUKUBA, IBARAKI 305, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	----	----	----	SYNCHR ONTRON ---- TELL-TERA	----	----	JAJ/10-20-89/050 10/20/89 F016E / / JA
07010 50B02 A F002A XRL 8	E	HITACHI LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101 ---- ---- DEVELOPED A PRACTICAL MODEL STORAGE RING	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 103, JAPAN ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR OTRON ----	----	----	JAK/VOL 7 #27/007 09/01/88 F002B / / JA
07010 50B02 A F032G XRL 39	E	NEC CORPORATION ---- NEC BLDG, 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A TT U	----	----	----	SYNCHR ONTRON ---- ELECTR ONIC ENERGY 2.5GeV , STORED CURRENT 500mA, ORBIT RADIUS 8.66m	----	----	JAJ/10-20-89/050 10/20/89 F016H / / JA

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07010 50B02 A F032G XRL 47	E	NEC CORPORATION, MICROELECTRONICS RESEARCH LABOARTORIES ---- 1-1 MIYAZAKI YONCHOME, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- K.OKADA, E.NOMURA, K,SUZUKI & K.FUJII ----	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORIES ---- 1-1 MIYAZAKI YONCHOME, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- E.KOUNO, Y.TANAKA & J.IWATA ----	NEC CORPORATION, RESEARCH & DEVELOPMENT PLANNING & TECHNICAL SERVICE DIVISION ---- 1-1 MIYAZAKI YONCHOME, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- Y.KAWASE ----	Y A DT U	----	----	----	SYNCHR ONTRON ---- SEE MEMO	----	----	JBL/VOL 60 # 7/01843 07/01/8 9 F018B / / JA
07010 50B02 A F032G XRL 24	E	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORY ---- 4-1-1, MIYAZAKI, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- K.FUJII & K.OKATA ----	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORY ---- R&D PLANNING & TECHNICAL SERVICE DIVISION, 1-1 MIYAZAKI, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- M.NAGANO & H.KURODA ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR ONTRON ----	----	----	JDY/VOL 6 #6/0212 8 12/01/8 8 F012A 06/01/8 8 JA
07010 50B02 A F032G XRL 64	E	NEC CORPORATION, MICROELECTRONICS RESEARCH LABS. ---- 1-1, MIYZAKI YONOCHOME, MIYAMAE-KU, KAWASAKI 213, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JDY/VOL 6 #1/0191 02/01/8 8 F027A / / JA

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07010 50B02 A F032G XRL 26	E	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 484, TSUKAGOSHI 3-CHOME, SAIWA-KU, KAWASKI 210, JAPAN ---- E.KOUNO, Y.TANAKA, J.IWATA, Y.TASAKI ----	NEC CORPORATION, PRODUCTION ENGINEERING DEVELOPMENT LABORATORY ---- 484, TSUKAGOSHI 3-CHOME, SAIWA-KU, KAWASAKI 210, JAPAN ---- E. KAKIMOTO ----	NEC CORPORATION, MICROELECTRONICS RESEARCH LABORATORIES ---- 1-1, MIYAZAKI 4-CHOME, MIYAMAE-KU, KAWASAKI, 213, JAPAN ---- K.OKADA, K.SUZUKI, K.FUJII & E.NOMURA ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR ONTRON ----	----	----	JDY/VOL 6 #6/0213 5 12/01/8 8 F013B 06/01/8 8 JA
07010 50B02 A F032A XRL 21	E	NIPPON TELEGRAPH & TELEPHONE ---- ATSUGI, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	SYNCHR ONTRON ----	----	----	JDQ/03- 01-89/0 65 03/01/8 9 F010A / / JA
07010 50B02 A F032A XRL 38	E	NIPPON TELEGRAPH & TELEPHONE ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A PP U	----	----	----	SYNCHR ONTRON ---- FORM 0.35um PATTER NS, 51 STAGE RING OSCILL ATOR	----	----	JAJ/10- 20-89/0 50 10/20/8 9 F016G 10/01/8 8 JA
07010 50B02 A F032A XRL 12	E	NIPPON TELEGRAPH & TELEPHONE CORP. (NTT) ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR ONTRON ----	----	----	JAK/VOL 8 #30/048 04/01/8 9 F006A 02/08/8 9 JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: X-RAY LITHOGRAPHY

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50B02 A F032A XRL 68	E	NIPPON TELEGRAPH & TELEPHONE CORP. (NTT) ---- ATSUGI, KANAGAWA PREF., JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A PP U	---- SEE MEMO	----	----	SYNCHR OTRON ----	----	----	JAK/VOL 8 #30/048 04/01/8 9 F030A 02/08/8 9 JA
07010 50B02 A F032A XRL 20	E	NIPPON TELEPHONE & TELEGRAPH ---- ?, JAPAN ---- ---- REPORT ON RECENT VISIT TO JAPAN INDUSTRIES BY DR. CHARLE M. FALCO	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 103, JAPAN ---- ----	---- ---- ----	Y A PE U	----	----	----	SYNCHR OTRON ----	----	----	JAO/VOL 13 #4/036 12/01/8 8 F009C 05/01/8 9 JA
07010 50B02 A F019B XRL 37	E	PHOTON FACTORY ---- OHO, TSUKUBA, IBARAKI 305, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	----	----	----	SYNCHR ONTRON ---- EXPERI MENTAL FACILI TY OF THE KEK	----	----	JAJ/10-20-89/0 50 10/20/8 9 F016F / / JA
07010 50B02 A F019C XRL 58	E	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- OHO, TSUKUBA-SHI, IBARAKI-KEN, 305, JAPAN ---- A. OGATA ----	THE UNIVERSITY OF TOKYO, RESEARCH CENTER FOR NUCLEAR SCIENCE & TECHNOLOGY ---- SHIRAKATA-SHIRANE, TOKAI-MURA, IBARAKI-KEN, 319-11, JAPAN ---- S. TAGAWA ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	SYNCHR ONTRON ---- TRISTA N	----	----	JBL/VOL 60 #7/0219 7 07/01/8 9 F022B / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: X-RAY LITHOGRAPHY

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07010 50B02 A F032E XRL 66	E	SORTEC CORPORATION ---- TSUKUBA, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P PP U	---- SEE MEMO	----	----	SYNCRO TRON ----	----	----	JAY/VOL 27 #1394/0 16 12/16/8 9 F029A 03/01/9 0 JA
07010 50B02 A F032B XRL 31	C	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORIES ---- SHIMAYA, KONOHANA, OSAKA 554, JAPAN ---- H.TAKADA & Y.TSUTSUI ----	ELECTROTECHNICAL LABORATORY ---- UMEZONO, TSUKUBA, IBARAKI 305, JAPAN ---- T.TOMIMASU & S.SUGIYAMA ----	---- ---- ----	Y A DT U	2 ----	----	----	SYNCHR ONTRON ----	----	----	JBL/VOL 60 #7/0163 0 07/01/8 9 F015A / / JA
07010 50B02 A F032B XRL 15	C	SUMITOMO ELECTRIC INDUSTRIES, LTD., OSAKA RESEARCH LABORATORY ---- SHIMAYA, KONOHANA OSAKA 554, JAPAN ---- HIROSHI TAKADA & KOUHEI FURUKAWA ----	MINISTRY OF INTERNATIONAL TRADE & INDUSTRY AGENCY OF INDUSTRIAL SCIENCE & TECH. ---- ELECTROTECHNICAL LABORATORY, SAKURA, NIIHARA IBARKI 305, JAPAN ---- TAKIO TOMIMASU ----	---- ---- ----	Y A DT U	02 ----	----	----	SYNCHR OTRON ----	----	----	JAS/VOL 27 #7/0552 07/01/8 8 F008B / / JA
07010 50B02 A F032C XRL 22	E	SUMITOMO HEAVY INDUSTRIES ---- 1-3, SHIYAMA 1-CHOME, KONOHANA-KU, OASKA 554, JAPAN ---- ---- SOR RING WILL BE CONSTRUCTED IN TANASHI, SUBURB OF TOKYO	---- ---- ----	---- ---- ----	Y P FP U	----	----	----	SYNCHR ONTRON ----	----	----	JDQ/07-09-87/0 52 07/09/8 7 F011A 05/01/8 8 JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
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07010 50B02 A F032C XRL 34	E	SUMITOMO HEAVY INDUSTRIES LTD. ---- OHTEMACHI, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	----	----	----	SYNCHRONTRON ---- NAMED - AURORA	----	----	JAJ/10-20-89/050 10/20/89 F016C / / JA
07010 50B02 A F032C XRL 69	E	SUMITOMO HEAVY INDUSTRIES, LTD. ---- 2-1, OHTEMACHI, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A PP U	---- SEE MEMO	----	----	SYNCHRONTRON ---- NAMED-AURORA	----	----	JBE/SER1512124189/01 12/15/89 F031A 12/15/89 JA
07010 50B02 A F032C XRL 19	C	SUMITOMO HEAVY METALS ---- TANASHI CITY, JAPAN ---- ---- REPORT OF VISIT TO SUMITOMO METALS BY DR. CHARLES M. FALCO	---- ---- ----	---- ---- ----	Y A DT U	0250 ----	----	----	COMPACT SYNCHROTRON ----	----	----	JAO/VOL13 #4/036 12/01/88 F009B 12/01/90 JA

Record#	PAGENO	DESCRAPPLC
1	F0000	X-RAY LITHOGRAPHY Conventional optical lithography is capable of producing microcircuit structures as small as 0.5 microns, which includes 1 megabit DRAMS (at 1.3um) and 4 Mbit DRAMS (at 0.8um). However, 16 Mbit DRAMS will require 0.5 to 0.3 micron feature size and 256 Mbit DRAMS are expected to use 0.1 micron feature sizes. Microcircuit structures of 0.5 microns and smaller are beyond the capability of optical lithography and must depend upon other technologies such as electron beam direct write, ion beam, laser-based deep-uv steppers, and X-ray steppers. Although E-beam is the most mature of the advanced submicron lithography technologies, and is regularly used for production of optical and X-ray masks and reticles, and for the prototype production of application-specific integrated circuits (ASIC's), it is to slow and uneconomical for direct writing onto individual silicon wafers in mass production. Of the remaining technologies only X-ray holds the promise of an economical process for submicron mass production. X-ray lithography inherently demonstrates higher resolution than conventional lithography because it uses shorter exposure wavelengths that result in reduced diffraction effects for feature sizes <0.5 um. Furthermore, registration precision can be achieved with low distortion reticles, since wafer-to-reticle site alignment systems exist that are applicable for X-ray proximity steppers. Wafers larger than 75mm dia. demand step-and-repeat systems, but such systems require higher sensitivty resists and much brighter X-ray sources than a conventional X-ray tube. Flatness of masks and the wafers is also crucial to an efficient production system.
44	F017A	We have constructed an exposure system based on a newly developed mask-to-wafer alignment technique for use in a 1/4um lithography with synchrotron radiation (SR) x rays. This system consists of optics for fine alignment along the horizontal axis, vertical mask and wafer stages, a position control system, and an aluminum chamber containing them. The alignment technique uses three diffraction gratings arranged symmetrically on the mask and the wafer and detects the relative displacement directly from the phase change of the beats of diffracted light. The chamber is filled with He gas in atmospheric pressure and separated from the SR beam line in ultra high vacuum by a 25 um-thick Be window. Using the present system, 1/2 um-wide patterns were printed to the wafer with an alignment accuracy better than 0.05um.
6	F001B	Japan will begin building an experimental synchrotron orbital ring for X-ray lithography in January. The synchrotron, built around a superconducting electromagnet, will be assembled in Tsukuba, Japan, at the Electrotechnical Laboratory of the Agency of Industrial Science and Technology, under the guise of the Ministry of International Trade and Industry and Sumitomo Electric Industries Ltd., of Osaka. The new synchrotron, which will have a 4-m-wide orbital ring, will use technology developed by the Electrotechnical Lab that increases the exposure area while maintaining a resolution of

less than 0.25 um. The system should be completed by October 1988.

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62 F026A A bright and reliable x-ray source for lithography has been developed using plasma focus. Discharge with constant pressure gas, one of the features of plasma focus, makes the x-ray source system simple and lengthens lifetime. A fine ceramic insulator made of alumina in place of a conventional Pyrex glass insulator improves system reliability. The system operates for more than 10^5 discharges without maintenance. The lifetime ofthe system is ten times longer than that of a conventional plasma focus device. The resolution of a pattern printed by multishot exposure depends not only on the diameter of pinched plasma but also on the variation of source position. A new spherical electrode surrounding the plasma-focusing space is added to stabilize the location of the spot on the axis by eddy currents which exert the Lorentz force on the plasma. The spot position deviation has become negligibly small as compared with the pinched plasma diameter. The x-ray source size for neon is 1mm in diameter and 10 mm in length. Consequently, 0.4um fine pattern has been printed with this source. Neon radiates intense x rays in opposite voltage polarity to that of a conventional plasma focus. Polarity inversion enables a very thin beryllium window to be located on the axis with the assistance of magnetic deflector and plasma stop. An x-ray intensity of 5 mJ/cm^2/shot 25 cm from the source with an irradiance of 10 mW/cm^2 at the 2-Siz repetition rate has been obtained. The plasma focus is a promising x-ray source for lithography from the viewpoint of intensity, resolution, and lifetime.

30 F014C Poly (phenyl methacrylate) (PPhMA) is utilized as a base resist of radiation-induced graft copolyerization for the purpose of high-throughput x-ray lithography. PPhMA has dry-etching resistance due to the aromatic ring in its side chain and, therefore, it can be used for large-scale integration (LSI) fabrication. Gaseous acrylic acid is graned into PPhMA film to produce a copolymer which is insoluble in the solvent of PPhMA. The graft processing enhances the resist sensitivity by three orders of magnitude to the level of 10 mJ/cm^2. The swelling of the grafted resist during development is drastically minimized by formation of a cross-linked structure in the grafted resist by thennal dehydration of acrylic acids. The above technique successfully provided a negative patten with feature size down to 0.3 um.

81 F034A

13 F007A

32 F016A SOR lithography is being expected to fill the need for half-submicron linewidth range pattern batch transfer technology for mass production. It is being especially regarded as most promising as a <= 0.25 um level transfer technology. At present, studies are being pushed in various places on such research and development themes as a subminiature SOR light source, a beam line exclusively for lithography, a vertical SOR stepper, an X-ray photomask, and an X-ray photoresist, but there are also many problems to be solved before their

practical use. This paper has reported on the atmospheric exposure system SOR lithography technology that NEC has developed heretofore. It now is only at the stage of the foundation of the system having been solidified, and the company intends to push further research and development hereafter toward its practical use. The author expects that 1989 might possibly be a year when we can find a good prospect to develop a subminiature SOR light source, and wishes to plan, provided that it can come true, a new development of R@D strategy with this as a turning point of great importance for promoting SOR lithography research.

46 F018A The atmospheric environmental exposure system for synchrotron radiation (SR) lithography has been integrated using the Photon Factory storage ring (2.5 GeV). The system, composed of a highly reliable beamline, an SR extracting chamber and a prototype SR stepper, aims at attaining higher accuracy and throughput. Based on a fail-safe mechanism notion, a double-vacuum protection system, in which two sets of a fast closing valve and acoustic delay line are installed in the main beamline and branch beamline, respectively, has been organized. Vacuum breakdown tests indicated that any vacuum breakdown, a beryllium (Be) window rupture in the worst case, exerts little influence on the storage ring ultrahigh vacuum. The SR extracting chamber, equipped with a Be window and an extraction window, is filled with helium at atmospheric pressure. Particularly, the 50mm-thick, 35-mm-diam Be window, vacuum-sealed by a Viton O-ring, was preliminanly employed and, so far, has operated successfully, giving a 25-mm square exposure area. In terms of practical availability and simplicity, the SR stepper in an atnlospheric environment has been constructed.

SYCHRONTRON RADIATION LITHOGRAPHY SYSTEM

STORAGE RING	PHOTON FACTORY (2.5 GeV)
ENLARGEMENT OF EXPOSURE AREA	OSCILLATING MIRROR
BEAMLINE	10^-9 TORR IN PRESSURE
VACUUM BREAKDOWN PROTECTION	2x(FCV+ADL)
WINDOW	Be(50um IN THICKNESS)
(SR STEPPER)	
EXPOSURE ENVIRONMENT	ATMOSPHERIC
RESOLUTION	0.25 um
EXPOSURE FIELD	25 mm SQUARE
ALIGNMENT ACCURACY	0.05 um (3o)

25 F013A A prototype synchrotron radiation (SR) stepper Sor quarter-micron devices has been developed and installed at the Photon Factory in the National Laboratory for High Energy Physics, Japan. The stepper features are, (i) exposure in an atmospheric environment, (ii) large exposure area (25-mm sq), and (iii) alignment error detection at all times, including during exposure. The stepper consists of an SR extracting chamber, precision mechanical stages, and an alignment error detection system. An SR beam in UHV goes through a beryllium window into an atmospheric environment, and covers the 25-mm sq exposure area by

using an oscillating mirror. Patterns on a mask are imprinted onto a wafer. Mask and wafer are, respectively, held in place with vacuum chucks. Their subsequent positioning movements are driven in 6 degrees of freedom by piezoelectric actuators for fine alignment and gap setting. The alignment system, based on the previous Fresnel lens optical system, newly employs a di@erential mode linear Fresnel zone plate alignment method. As the optical system for this method is located at the outside ofan SR beam, it can detect an alignment error between a mask and a wafer at all times, including during exposure. Patterns measuring 0.2um were completely successfully imprinted on a wafer. Until now, 0.03-um (3o) positioning accuracy and 0.2um (3o) overlay accuracy were achieved.

9 F003A The Osaka University Laser Nuclear Fusion Research Center has developed an x-ray lithography device that will pave the way for 64 and 100 Mbit DRAM·production. The device, which uses 10-watt x-rays, is capable of printing 0.1-micron-wide circuit patterns. Use of x-rays is considered necessary in 64 Mbit or larger DRAM production. At present, more than 10 domestic companies are developing an SOR (synchrotron orbit radiation) device as an x-ray generating machine.

57 F022A This article discusses pulse radiolysis using synchrotron radiation from the TRISTAN accelerators, the accumulation ring (AR) and the main ring (MR) . They provide intense radiation, the energy of which goes up to the y-ray region, and a pulse length below 50 ps, which could be below 10 ps. The time separation between neighboring bunches is 1.25 us at the AR and 5 us at the MR. These features should make it possible to detect reactive intermediates in radiation-induced reactions in the time span from picoseconds to microseconds. Possible applications of the picosecond synchrotron radiation pulse radiolysis are introduced. They include studies of radiation effect on resist materials, on radiation sensitive materials, biological systems, and reaction from selected states such as Rydberg state, inner-shell excited states, and multi-ionized states.

APPLICATIONS

Picosecond SR pulse radiolysis is a new, powerful method, and will be used in a very wide field. Here, several possible applications are picked up.

A. Radiation effects on resist materials for x-ray lithography

A number of papers have been published on radiolysis of resist materials using Co y rays (1.17 MeV, 1.33 MeV). The short-lived intermediates have been studied by electron pulse radiolysis. In the actual field of x-ray lithography, however, x rays of several kiloelectron volts are used. Now we can directly study the short-lived species to clear the reaction mechanisms by using picosecond SR pulse radiolysis.

67 F029B Sortec Corp. has develop̣d a Y3 billion synchrotron orbital radiation (SOR) light source system for

lithographing microcircuits on next-generation 64-megabit semiconductors. In March, the firm began trial operations of the system at its laboratory in Tsukuba, northeast of Tokyo.

Nippon Telegraph and Telephone Corp. has tentatively built a similar system, but Sortec's SOR can process 20-30 wafers an hour, effectively the largest output in the world. The company hopes to develop the penpherial equipment for mass-producing next-generation semiconductors by the end of next February.

Current lithography techniques based on ultraviolet rays may not be suitable for production of next-generation semiconductor because such chips need shorter-wavelength X-rays for the lithographing process. Industrial sources say the SOR system is expected to be the leading technology in develop mass-production facilities next-generation semiconductors, even though an X-ray laser lithography system is already under development.

The SOR system rotates electrons in a vacuum ring at a speed approaching that of light, and emits strongly directive X-rays by means of deflection magnet inside the ring.

Sortec, capitalized at 1.28 billion, was established in June 19866 as a joint venture between the Japan Key Technology Center and 13 electronics makers, including Toshiba Corp, Hitachi, LTD., Mitsubisi Electric Corp., NEC Corp., and Fujitsu Ltd. The Japan Key Technology Centerr, set up in October 1985, is funded by profits from the public sale of NTT shares.

14 F008A In the work reported here, we estimate the design parameters of a superconductive synchrotron radiation (SR) ring employing the electron undulating method, which is capable of large-area exposure of SR. The optimum electron energy is found to lie in the range 0.6 to 0.7 GeV with a magnetic field of 4.0T to 4.5T and a beam current in the range 200 to 300mA. Research into the miniaturization of the SR ring and its injector to complete a practical SR system has continued. In particular, low/energy injection improves the cost effectiveness of the SR system, but this requires further study. Therefore, the Electrotechnical Laboratory (ETL) of the Japanese Ministry of International Trade and Industry and Sumitomo Electric Industries, Ltd., jointly completed "NIJI-1 ," the firsT compact normal-conductive SR ring in the world designed for low/energy injection studies. we succeeded in making the first beam storage in February 1986 and since then have achieved the storage of a beam current of more than 200 mA of 163-MeV electrons; its 1/e lifetime was about 50 min. Research on topics such as high efficiency injection at low/ energy and miniaturization of the injector is continuing.

2 F000

X-RAY RADIATION SOURCES

X-ray Tubes

X-ray tubes are the simplest x-ray sources, in which high energy electrons are focused onto a palladium target, and which emit

X-rays with an efficiency of less than 1%, while the remainder of the energy is wasted heating the target. The level of power produced can be increased by employing a high velocity flow of coolant around the target. The most widely used design is an inverted cone that combines a large coolant surface with a small symmetric projected spot size. These sources range from 4 to 7 kW in a 3mm spot. High velocity coolants permit power densities of 60kW/cm^2. Such power densities are adequate for full wafer exposure but not for step-and-repeat use. A technique using rotating anodes permits delivery of considerably higher power but rapidly degrades as a carbonaceous material deposits on the anode.

Synchrotron

Synchrotron radiation provides an alternative source of high output x-rays. This radiation is emitted by electrons in response to their radial accelerations while they are maintained in circular orbits within a storage ring or synchrotron. The x-rays from this device are nearly collimated (a small diameter, non-spreading beam) and can provide flux densities in excess of 10-20 mW/cm^2 at the wafer plane. The radiation beam uniformity from this source is the 10-50 angstrom range, which is strongly absorbed by the thin absorber patterns of the (gold) x-ray masks. The major disadvantage of the synchrotron source is cost, which can exceed $10 million for a multiport sytem. Further, any system problem can cause all ports to be shut down, making downtime extremely expensive. There are very few synchrotron facilties worldwide. BESSY and COSY reside at Fraunhofer Institute in W.Germany, one is being built in France for joint European use, and there are two or three in the U.S.

Laser Plasma

A third source of X-rays is the laser plasma approach, in which either a pulsed IR laser or a UV excimer laser is used with pulse widths varying from 50 picoseconds to 10 nanoseconds. The beam is focused on the target, where it creates a plasma of sufficiently high temperature to produce continuous and characteristic X-ray radiation. One system has provided a 12% conversion effciency from laser power to useful X-rays, but further gains are limited by materials. The emitted energy density can be as high as 6.3 mW/cm^2, which is some 50 times brighter than electron impact sources. Another major advantage is that the power supply can be located remote from the aligner, thus saving valuable clean room space and avoiding problems from electromagnetic interference. Current research is aimed at increasing the pulse repetition rate while reducing peak power, and decreasing the amout of debris deposited on the X-ray window, by firing the laser in synchronism with a shutter. The debris is caused by target ablation as it is struck by the laser beam.

65 F028A SUBJ : FOREIGN PRESS NOTE--FB PN 89-284--JAPAN
SOURCE : FOREIGN BROADCAST INFORMATION SERVICE PROD GROUP

JAPAN : COMPACT SYNCHROTRON ORBITAL RADIATION

ACCORDING TO RECENT TOKYO PRESS REPORTS, THE JAPANESE HAVE TAKEN THE LEAD IN RESEARCH ON THE USES OF SYNCHROTRON ORBITAL RADIATION (SOR) AS A SOFT X-RAY LITHOGRAPHIC SOURCE FOR THE FABRICATION OF ULTRA-LARGE-SCALE INTEGRATED CIRCUITS (ULSIS). IN AUGUST AND

SEPTEMBER ALONE, FOUR FACILITIES FOR X-RAY LITHOGRAPHY BEGAN SUCCESSFUL OPERATIONS IN EXTRACTING SOR. SEVEN WILL BE IN OPERATION BY THE END OF 1989 .

THE TOKYO PRESS REPORTS THAT WHILE SOR CAN BE APPLIED IN A WIDE RANGE OF FIELDS, INCLUDING NEW MATERIALS DEVELOPMENT, MEDICINE, BIOTECHNOLOGY, BASIC PHYSICS , AND CHEMISTRY, IT HAS ITS GREATEST APPLICATIONS FOR THE MICROELECTRONICS INDUSTRY. SOR IS CONSIDERED SUITABLE FOR DRAWING CIRCUIT WIDTHS OF LESS THAN 0.2 MICRONS. SOR WAVELENGTHS CONSIDERED MOST SUITABLE FOR X-RAY LITHOGRAPHY RANGE FROM 0.5 TO 1 NANOMETERS. ELECTRON ENERGIES REQUIRED FOR X-RAY GENERATION ARE 0.6 TO 1 GIGA ELECTRON VOLTS (GEV).

EKONOMISUTO ON 27 JUNE REPORTED THAT THE SUPERIORITY OF SOR LITHOGRAPHY OVER CONVENTIONAL PHOTOLITHOGRAPHY HAD BEEN CONFIRMED BY SCIENTISTS AT THE NATIONAL LABORATORY FOR HIGH-ENERGY PHYSICS IN TSUKUBA USING THE LARGE PHOTON FACTORY RING. BEFORE SOR CAN BE USED IN PRACTICE FOR LITHOGRAPHY, AN ECONOMICAL, COMPACT SOR X-RAY FACILITY FOR FABRICATING ULSI CIRCUITS MUST BE DEVELOPED. THE JAPANESE GOVERNMENT AND INDUSTRY HAVE THEREFORE BEEN ENTHUSIASTICALLY ENGAGED IN DEVELOPING SUCH FACILITIES . ACCORDING TO VARIOUS PRESS SOURCES, INCLUDING THE OCTOBER NIKKEI MICRODEVICES, FOUR COMPACT FACILITIES FOR EXTRACTING SOR BEGAN OPERATIONS IN AUGUST AND SEPTEMBER, AND SEVEN FACILITIES WILL BE READY FOR OPERATIONS BY THE END OF 1989. TWO OTHER FACILITIES ARE IN THE PLANNING STAGE.

70 F031B SUMITOMO HEAVY INDUSTRIES SAID IT HAS SUCCEEDED IN EXTRACTING SYNCHROTRON ORBITAL RADIATION FROM A STORAGE RING WITH A SUPERCONDUCTING MAGNET TO BEND A STREAM OF ELECTRONS. MORE THAN 17 SOR RINGS ARE CURRENTLY USED IN JAPAN, BUT A MAJORITY OF THEM ARE QUITE LARGE MACHINES WITH THEIR PRINCIPAL PURPOSES BEING ACADEMIC RESEARCH, ACCORDING TO DATAQUEST JAPAN, A COMPANY SPECIALIZING IN SURVEYING THE COMPUTER INDUSTRY.

FIVE DOMESTIC AND OVERSEAS LABORATORIES, INCLUDING THOISE OF SUMITOMO HEAVY INDUSTRIES AND NIPPON TELEGRAPH AND TELEPHONE CORP. (NTT), ARE DEVELOPING COMPACT SOR RINGS DESIGNED FOR VLSI PRODUCTION, ACCORDING TO THE COMPANY. SUMITOMO, HOWEVER , SAYS IT IS THE ONLY COMPANY THAT HAS VIRTUALLY COMPLETED THE OVERALL STRUCTURE PROCESSING SYSTEM FOR OVER 64-MAGABIT MEMORY CHIPS USING THE SOR RING.

18 F009A Canon will have a first generation, grazing incidence x-ray lithography exposure system ready for delivery with the first of the compact synchrotrons being developed by several Japanese companies. Canon is testing some of these components now at the Photon Factory in Tsukuba. It is interesting to note that beam time at the Tsukuba synchrotron costs private companies Y50,000/h (about $385). Canon is actively conducting research aimed at a second-generation system based on multilayer coatings. Nikon although Canon doesn't know what fraction of Nikon's effort is devoted to multilayers.

If past experience is repeated, these early generation x-ray lithography installments will be in the hands of Japanese manufacturers several years before production versions are offered for sale elsewhere. This will

give them a head start of several years on non-Japanese companies, unless the United States takes a more active role. Already Japan has six of the world's ten largest manufacturers of semiconductors, including the top three.

Unfortunately, there was no time to learn about Canon's superconductiviy work during this visit. When I asked why a camera company had a superconductivity program, I was told that "no Japanese electronics manufacturer can afford not to have an active research program in this field."

45 F017B We have constructed an exposure system based on a newly developed mask-to-wafer alignment technique for use in a 1/4um lithography with synchrotron radiation (SR) x rays. This system consists of optics for fine alignment along the horizontal axis, vertical mask and wafer stages, a position control system, and an aluminum chamber containing them. The alignment technique uses three diffraction gratings arranged symmetrically on the mask and the wafer and detects the relative displacement directly from the phase change of the beats of diffracted light. The chamber is filled with He gas in atmospheric pressure and separated from the SR beam line in ultra high vacuum by a 25 um-thick Be window. Using the present system, 1/2 um-wide patterns were printed to the wafer with an alignment accuracy better than 0.05um.

33 F016B

72 F032B Eletrotechnical Laboratory and Private Companies

Funded by the Research Development Corporation of Japan,the Electrotechnical Laboratory and four privatecompanies (Sumitomo Electric, Mitsubishi Electric,Toshiba, and Shimadzu) have been engaged in development of the NIJI-1 and NIJI-II facilities for a number ofyears. NIJI-I began operation in February 1986 and ceasedoperation in March 1989, NIJI-II first produced SOR inAugust 1989. NIJI-III, under development by theElectrotechnical Laboratory and Sumitomo Electric,consists of four electromagnets which accelerateelectrons by vibration.

NAME OF FACILITY	NIJI-I	NIJI-II	NIJI-III
ORGANIZATION	SEE ABOVE		
ELECTRON ENERGY (GeV)	0.27	0.6	0.18
ORBITAL RADIUS (m)	0.7	1.4	0.5
WAVELENGTH (nm)	19.9	3.6	1.17
INJECTION METHOD	LINEAR ACCELERATOR (ALL)		
INJECTION ENERGY (MeV)	150	150	150
MAGNET	NORMAL CONDUCTING FOR I & II		SUPER-CONDUCTING
SIZE	4	5	4
STATUS	CEASED	8/89	10/89

5 F001A Japan will begin building an experimental synchrotron orbital ring for X-ray lithography in January. The synchrotron, built around a superconducting electromagnet, will be assembled in Tsukuba, Japan, at the Electrotechnical Laboratory of the Agency of Industrial Science and Technology,

under the guise of the Ministry of International Trade and Industry and Sumitomo Electric Industries Ltd., of Osaka. The new synchrotron, which will have a 4-m-wide orbital ring, will use technology developed by the Electrotechnical Lab that

increases the exposure area while maintaining a resolution of less than 0.25 um. The system should be completed by October 1988.

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36 F016E
8 F002B Lithography by means of X-ray exposure is commonly usedto form a supefine circuit pattern for 64-Mbit VLSIs. Asa source of X rays, there is a need for compactisation of synchrotron orbit radiation (SOR). In SOR, electronstravel at a speed approaching that of light. When theroute of travel is bent by electro-magnet, light ispojected on the extended line of the preceding track. Thewavelength of the light is determined by the amount ofkinetic energy of electrons and the intensity of theelectromagnet's magnetic field. All types of light can betaken out and high luminance of X rays of 5 to 10 Aobtained for X-ray exposure.

The SOR installed at the National Laboratoy for HighEnergy Physics in Tsukuba measured a massive 68m inlength, 50 m in breadth and 400 m in linearity. A smallerversion has thus been sought after. With the cooperationof Hitachi and Toshiba, NTT has now devel-
oped a practical model with a 5-m storage ring. Cost ofdevelopment was Y20 billion.

56 F021B Soft x-ray absorption spectra and spectral sensitivity of x-ray resists are studied by using synchrotron radiation. Spectral sensitivity is successfully evaluated from the fragment yield change of the decomposed resists by changing incident x-ray wavelengths. This evaluation method is newly developed here. Using this technique, x-ray wavelength dependency for the decomposition efficiency of polymer resists poly (2-methylpentene- 1 -sulfone) and their decomposition characteristics are clarified. These are very important for development of more x-ray resists.

63 F026B A bright and reliable x-ray source for lithography has been developed using plasma focus. Discharge with constant pressure gas, one of the features of plasma focus, makes the x-ray source system simple and lengthens lifetime. A fine ceramic insulator made of alumina in place of a conventional Pyrex glass insulator improves system reliability. The system operates for more than 10^5 discharges without maintenance. The lifetime ofthe system is ten times longer than that of a conventional plasma focus device. The resolution of a pattern printed by multishot exposure depends not only on the diameter of pinched plasma but also on the variation of source position. A new spherical electrode surrounding the plasma-focusing space is added to stabilize the location of the spot on the axis by eddy currents which exert the Lorentz force on the plasma. The spot position deviation has become negligibly small as compared with the pinched plasma diameter. The x-ray source size for neon is 1mm in diameter and 10 mm in length. Consequently, 0.4um fine pattern has been printed with this source. Neon radiates intense x rays in opposite voltage polarity to that of a conventional plasma focus. Polarity inversion enables a very thin beryllium window to be located on the axis with the assistance of magnetic deflector and plasma stop. An x-ray intensity of 5 mJ/cm^2/shot 25 cm from the source with an irradiance of 10 mW/cm^2 at the 2-Hz repetition rate has been obtained. The plasma focus is a promising x-ray source

for lithography from the viewpoint of intensity, resolution, and lifetime.

74 F032D Ishikawajima-Harima Heavy Industries

Ishikawajima-Harima Heavy Industries (IHI) set up itsLUNA SOR facility in April and generated its first SOR inAugust 1989. The IHI facility has a square storage ringwith four electromagnets, each of which provides a90-degree deflection.

NAME OF FACILITY	LUNA
ORGANIZATION	SEE ABOVE
ELECTRON ENERGY (GeV)	0.8
ORBITAL RADIUS (m)	2.0
WAVELENGTH (nm)	2.18
INJECTION METHOD	LINEAR ACCELERATOR
INJECTION ENERGY (MeV)	45
MAGNET	NORMAL CONDUCTING
SIZE	6.6 m
STATUS	OPERATIONAL 8/89

11 F005A RIKEN is currently engaged construction of a nextgeneration sychrotron radiation facility. The facility,with a stored electron of 6-8 GeV, is expected to make asignificant contribution to basic research in manyfields including material science, life science,information and electronic science, nuclear R&D, andoptical science.

Highenergy electrons emit synchrotron radiation when they are deflected in a magnetic field. This radiation hasmany excellent features: it is very intense, polarised,and well collimated beams with a continuous spectrumranging from far infrared rays.

Construction of the new facilityu will be coodinated bythe Science & Technology Agency using a 140-ha site inHarima Science Park City donated by Hyogo Prefecture.Financial support for construction, which is expected tocost Y100 billion, will be provided by the government.

The facility consists of a main storage ring, a booster synchrotron pre-injector linacs. The main storage ringis a light source ring with a circumference of about 1.5km, or eight times larger than the Photon Factory ring atthe National Laboratory High-Energy Physics.

Construction will be undertaken jointly by the JapanAtomic Energy Research Institute and RIKEN the formerbeing responsible for the linacs and synchrotron, andthe latter for the storage ring.

In FY1987, research funds of Y65 million were providedfor this project and design work was started. In FYI988(budget approx. Y612 million), beam dynamicalcalculations were extensively performed. Development anddesign work has almost been completed for theaccelerating cavity, the vacuum chambers and pumps, andthe magnets. Prototypes soon. For FY1989, a budget ofYI,900 million has been provisionally allocated. Sitepreparation and installation of equipment are scheduledto take place from I990 to I994, and the first injectionof a beam in the following year. Regular use of thefacility for research purposes is scheduled for 1998.

78 F033A SX-5 X-Ray Stepper

The SX-5 X-ray stepper used in this test-manufacture has been developed as a lithography system that can

cope with VLSI of 0.5 um or below. In order to attain high resolution, measures have been taken to make the mask-wafer gap very small (15 um), thereby restraining the penumbra blur that most affects the resolution. In manufacturing VLSI, X-ray stepper and photo-stepper are expected to be used simultaneously. Therefore, the alignment mark for the SX-5 has been made the same alignment mark as the Nikon-made "NSR" photo-stepper. The maximum exposure area has been set at 29x 29 mm^2 so that it can cope with future chip size increase. The X-ray source is an electron-beam excitation-type source using a rotating target made of palladium (Pd). Table 1 shows the specifications for the SX-5 X-Ray stepper.

Table 1. Specifications for SX-5 X-Ray Stepper

Mask Size	Outer Diameter: 76mm Thickness: 0.38 mmt
Wafer Size	Outer Diameter: 76-150 mm
Minimum Exposure Area	11x11 mm^2
Maximum Exposuer Area	29x29 mm^2
Alignment Accuracy	+/-0.15um mean of x+3o
Mask Wafer Gap	15um
Source-Mask distance	200mm
Penumbra Blur	0.23um
X-Ray source type	Electron-beam excitation
Wavelength	4.37 angstrom
Power	10kW
Effective source size	3mm

10 F004A In the area of x-ray lithography research, MITI and 13companies have formed SORTEC (the Synchrotron Orbital Ring Technology Consordium) to study the use of smallsynchrotrons as radiation sources in semiconductor fabrication. If processes can b e developed to usesynchrotron radiation for direct x-ray writing, circuitswith feature sizes of as small as 0.2 microns can be mass-produced. An ion-beam facility in the Kansai area,planned for fall of 1988 by MITI as pad of itsIndustrial Techno
logy R&D Organization initiative, willstudy focused ion-beam pattern generation, a process which is expected to reduce the scale of defects in x-rayphotographic masks.

76 F032F Mitsubishi Electric

Mitsubishi Electric's Central Research Institute hasdesigned a SOR facility 3 meters in diameter that isexpected to generate energy equal to that produced bylarger facilities. It will be shaped like a race track, with a straight portion of approximately 3.7 meters and acurved portion with an average radius of 1.5 meters. Electrons would be injected into the straight portion onone side and orbited in an accelerating tube, their speedbeing increased by a high-frequency accelerator. Superconducting electromagnets will be used for thecurved portion. A simulation test showed that if theintensity of the electromagnet was set at 4.44 tesla,electrons could be accelerated to 2 GeV, and X-rays with wavelengths of up to 0.358 angstrom would be generated. The facility is reported to be still under development, with no timetable yet announced for the beginning ofoperations.

ELECTRON ENERGY (GeV)	13
ORBITAL RADIUS (m)	1.5
WAVELENGTH (nm)	0.105
INJECTION METHOD	SYNCHROTRON
INJECTION ENERGY (MeV)	650

MAGNET	SUPERCONDUCTING
SIZE	16.8
STATUS	PLANNING

35 F016D
77 F032G NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS

PHOTON FACTORY IS NOT CONSIDERED A COMPACT FACILITY BUTIS INCLUDED BECAUSE IT HAS A BEAM LINE SPECIFICALLYDESIGNED FOR GENERAL PURPOSE RESEARCH.

NAME OF FACILITY	PHOTON FACTORY
ELECTRON ENERGY (GeV)	2.5
ORBITAL RADIUS (m)	8.66
WAVELENGTH (nm)	0.31
INJECTION METHOD	LINEAR ACCELERATOR
INJECTION ENERGY (MeV)	2500
MAGNET	NORMAL CONDUCTING
STATUS	OPERATIONAL 1983

7 F002A Lithography by means of X-ray exposure is commonly usedto form a supefine circuit pattern for 64-Mbit VLSIs. Asa source of X rays, there is a need for compactisation of synchrotron orbit radiation (SOR). In SOR, electronstravel at a speed approaching that of light. When theroute of travel is bent by electro-magnet, light ispojected on the extended line of the preceding track. Thewavelength of the light is determined by the amount ofkinetic energy of electrons and the intensity of theelectromagnet's magnetic field. All types of light can betaken out and high luminance of X rays of 5 to 10 A obtained for X-ray exposure.

The SOR installed at the National Laboratoy for HighEnergy Physics in Tsukuba measured a massive 68m inlength, 50 m in breadth and 400 m in linearity. A smallerversion has thus been sought after. With the cooperationof Hitachi and Toshiba, NTT has now devel-
oped a practical model with a 5-m storage ring. Cost ofdevelopment was Y20 billion.

39 F016H
47 F018B The atmospheric environmental exposure system for synchrotron radiation (SR) lithography has been integrated using the Photon Factory storage ring (2.5 GeV). The system, composed of a highly reliable beamline, an SR extracting chamber and a prototype SR stepper, aims at attaining higher accuracy and throughput. Based on a fail-safe mechanism notion, a double-vacuum protection system, in which two sets of a fast closing valve and acoustic delay line are installed in the main beamline and branch beamline, respectively, has been organized. Vacuum breakdown tests indicated that any vacuum breakdown, a beryllium (Be) window rupture in the worst case, exerts little influence on the storage ring ultrahigh vacuum. The SR extracting chamber, equipped with a Be window and an extraction window, is filled with helium at atmospheric pressure. Particularly, the 50mm-thick, 35-mm-diam Be window, vacuum-sealed by a Viton O-ring, was preliminanly employed and, so far, has operated successfully, giving a 25-mm square exposure area. In terms of practical availability and simplicity, the SR stepper in an atnlospheric environment has been constructed.

SYNCHRONTRON RADIATION LITHOGRAPHY SYSTEM

STORAGE RING	PHOTON FACTORY (2.5GeV)
ENLARGEMENT OF EXPOSURE AREA	OSCILLATING MIRROR
BEAMLINE	10^-9 TORR IN PRESSURE
VACUUM BREAKDOWN PROTECTION	2X(FCV+ADL)
WINDOW	Be(50um IN THICKNESS)
(SR STEPPER)	
EXPOSURE ENVIRONMENT	ATMOSPHERIC
RESOLUTION	0.25um
EXPOSURE FIELD	25 mm sq
ALIGNMENT ACCURACY (TARGET)	0.05 um (3o)

24 F012A A novel oscillating mirror system in the synchrotron radiation lithography beam line, installed in the Photon Factory storage ring (2. 5 GeV) , has been studied with special reference to scanning speed control for the synchrotron radiation beam. Concerning an oscillating mirror used in the total reflection region, it should be noted that the cuttoff x-ray wavelength depends on the glancing angle. That is, the total photon energy Sor the reflected varies as a function of the position of the beam irradiating the wafer. An oscillating mirror system has been investigated, in which the scanning speed for the synchrotron radiation beam can be controlled as a function of the glancing angle of the synchrotron radiation beam with reference to the mirror. Exposure result achieved using the oscillating mirror system, showed that extremely high x-ray dose uniformity,+- 3%, was obtained over the 25-mm-sq. exposure area.

64 F027A The reliable beamline structure for synchrotron radiationlithography has been investigated using the PhotonFactory storage ring (2.5 GeV). The recently builtbeamline aims at attaining system reliability and safety.This beamline, one of three branch lines split from abasic beamline, is a 10^-7 Pa ultrahigh-vacuum system with an oscillating mirror. In addition to a 40ms fastclosing valve (FCV) and an acoustic delay line (ADL),installed in the basic beamline, a <15 ms FCV and 40 msADL were set up to protect the storage ring fromaccidental breakdown. The FCV and ADL were placed forupstream of the oscillating mirror, to cope withaccidental gas leakage caused by the osciliatingmechanism. A vacuum breakdown test demonstrated that the FCV and ADL are greatly effective in vacuum protection.In order to protect operators from x-ray exposure, twoauxiliary shutters made of tantalum were placed upstreamof the oscillating mirror. The oscillating mirror, driventhrough bellows by a combination of a direct currentservomotor and a cam mechanism, enabled a highly reliableoscillation. A double-structured bellows was adopted toprovide against gas leakage. In addition, a siliconcarbide plane mirror (40 x 17 X 4cm) was employed becauseof its high-heat-resistance capability.

26 F013B A prototype synchrotron radiation (SR) stepper Sor quarter-micron devices has been developed and installed at the Photon Factory in the National Laboratory for High Energy Physics, Japan. The stepper features are, (i) exposure in an atmospheric environment, (ii) large exposure area (25-mm sq), and (iii) alignment error detection at all times, including during exposure. The stepper consists of an SR extracting chamber, precision mechanical stages, and an

alignment error detection system. An SR beam in UHV goes through a beryllium window into an atmospheric environment, and covers the 25-mm sq exposure area by using an oscillating mirror. Patterns on a mask are imprinted onto a wafer. Mask and wafer are, respectively, held in place with vacuum chucks. Their subsequent positioning movements are driven in 6 degrees of freedom by piezoelectric actuators for fine alignment and gap setting. The alignment system, based on the previous Fresnel lens optical system, newly employs a di@erential mode linear Fresnel zone plate alignment method. As the optical system for this method is located at the outside ofan SR beam, it can detect an alignment error between a mask and a wafer at all times, including during exposure. Patterns measuring 0.2um were completely successfully imprinted on a wafer. Until now, 0.03-um (3o) positioning accuracy and 0.2um (3o) overlay accuracy were achieved.

21 F010A Japanese researchers now have a working synchrontronstorage ring with superconducting magnets thats almostsmall enough to be used on a fabrication line forultra-large scale integrated circuits. The new storagering provides the 7A unit peak soft X-Raysneeded forlithography to fabricate devices with 0.2um or smallersdesign rules. The racetrack shaped ring is at a NipponTelegraph & Telephone Corp. office in Atsugi. At about2.5 by 5m, it accelerates electrons to the required 600million electron volts, and the associated linearaccelerator that injects electrons into the ring is only1.7m long. The normal temperature magnet ring thefacility has used until now measures 15 by 15m.

38 F016G

12 F006A On Feb. 8, Nippon Telegraph & Telephone Corp. (NTT) announced the extraction of synchrotron orbital radiation (SOR) using a compact superconducting storage ring and linear accelerator at its facility in Atsugi,Kanagawa Pref. This success, achieved by accelerating electrons to an energy level of 600MeV, marks the first time SOR has been extracted using a compact ring equipped with a superconductor magnet.

The signficance of this latest expenment is enormous for the electronics industry, demonstrating as it does the feasibility of compact, economical SOR facilities for fabricating super ULSI circuits.

At present, ultraviolet light is used in photolithography to draw circuits on chips, but the further integration of semiconductor memories is limited by the wavelength or the light used. In order tocreate ULSI circuits with memory capabilities exceeding 100 Mbit, it will be necessary to draw lines in the width range of 0.2 um. For this reason NTT has been developing lithography technology which will apply SOR.
A major task, to be undertaken before SOR could be usedfo lithography was to develop an economical, compact SOR facility. The superiority of SOR lithography over conven-tional photo-lithography had been confirmed by scientistsat the National Laboratory for High-Energy Physics in Tsukuba, using the large "Photon Factory" ring. Followingthis cofirmation, NTT began developing an experimental compact facility in 1984.

NTT's SOR facility consists of a linear accelerator(1.7m), a normal conducting ring (15X15 m), and asuperconducting storage ring (2.5X8m), and in June 1988, the company announced that it

had succeeded in extract-
ing SOR using the linear accelerator and the normalconducting ring, marking the first step towards the realisation of a compact facility for ULSI circuitfabrication.

In the latest experiment, SOR was extracted by directlyinjecting electrons at 15 MeV from the linear accelerator into the ring equipped with a superconductor magnet, andthen accelerating them in the ring to the targeted energy level of 600 MeV.

68 F030A On Feb.8, Nippon Telegraph & Telephone Corp. (NTT) announced the extraction of sychrotron orbital radiation (SOR) using a compact superconducting storage ring and linear accelerator at its facility in Atsugi, Kanagawa Pref. This success, achieved by accelerating electrons to an energy level of 600 MeV, marks the first time SOR has been extracted using a compact ring equipped with a superconductor magnet.

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In the latest experiment, SOR was extracted by directly injecting electrons at 15 MeV from the linear accelerator into the ring equipped with a super-conductor magnet, and then acceleraing them in the ring to the targeted energy level of 600 MeV.

71 F032A Nippon Telegraph and Telephone

Nippon Telegraph and Telephone (NTT) is the Japanese leader in synchrotron orbital radiation research,according to press reports, NTT began developing itsfirst experimental compact facility, called the NTT-1, in1984 and in May 1988 successfully produced SOR using alinear accelerator and conventional magnets. NTT wasagain able to produce SOR in February 1989 at itsfacility in Atsugi, Kanagawa Prefecture using a linearaccelerator and a

compact superconducting storage ring.This second NTT SOR facility, Super-Alis, consists of a 1.7-meter linear accelerator and a 2.5 x 8.8-metersuperconducting storage ring. SOR was generated bydirectly injecting electrons at 15 megaelectronvolts(MeV) from the line accelerator into the ring andaccelerating them in the ring to 0.6 GeV. This reportedlymarked the first time SOR had been generated using a compact ring with a superconducting magnet.

NAME OF FACILITY	NTT-1	SUPER-ALIS
ORGANIZATION	NTT	NTT
ELECTRON ENERGY (GeV)	0.8	0.6
ORBITAL RADIUS (m)	1.85	0.67
WAVELENGTH (nm)	2.02	1.73
INJECTION METHOD	LINEAR ACCELERATOR (BOTH)	
INJECTION ENERGY (MeV)	15	15
MAGNET	NORMAL CONDUCTING	SUPER CONDUCTING
SIZE		2.5x8.8m
STATUS		OPERATIONAL 2/89

20 FC09C A big market is projected for such systems, for x_raylithography, biomedical imaging, and material analysis.
NTT is presently installing a synchrontron made byToshiba for lithography. NTT's machine is scheduled to befunctional before the summer of 1989. A recent article inSynchrotron Radiation News estimates about 175 of suchsynchrotrons will be needed within the next ten years tosupply the demand for X-ray lithography alone.

37 F016F

48 F019A This article lists significant parameters of synchrotron radiation facilities in operation, under construction, or being planned, in twelve countries. It was prepared from information supplied on questionnaires sent to each facility. We are grateful to the scientists who provided the details; their nanes appear in the individual sections.

Table I summarizes the major faacities now in operation or under construction. Much greater detail for each facility is given in separate sections.

TABLE I. Synchrotron radiation sources in operation and in construction (no machines for industrial use are included). E is the typical electron beam energy and e is the characteristic photon energy of bending-magnet radiation. O = Operational, C = (Construction, D = Dedicated, PD = Partly Dedicatd, Par = parasitic, I= Inactive.

Location	Ring (Lab)	E(GeV)	e(keV)	Notes
China				
Bejing	BEPC(IHEP)	1.55-2.8	3.8 (2.6GeV)	C,PAR
Hefei	HESYRL (USTC)	0.8	0.52	C,D
France				
Orsay	DCI (LURE)	1.85	3.7	O,D
	Super ACO(LURE)	0.8	0.67	O,D
Grenoble	ESRF(ESRF)	6.0	19.2	C,D
Germany				
Hamburg	DORISII(DESY)	3.7-5.3	22.7(5GeV)	O,PD
W. Berlin	BESSY I(BESSY)	0.805	0.65	O,D
	COSY II(BESSY)	0.63		C,D

India				
Rajendranagar	Indus-1 (CAT)	0.45	0.2	C,D
Italy				
Frucati	ADONE(INFN)	1.5	1.5	O,PD
Trieste	ELETTRA	2.0	3.2	C,D
Japan				
Tsukuba	Photon Factory(KEK)	2.5	4.0	O,D
	TRISTAN AR (KEK)	5.8-6.5	20.7 (6 GeV)	O,PD
	TRISTAN MR (KEK)	30.0	244.0	O,PD
	TERAS (ETL)	0.8	0.57	O,D
	NIJI-I(ETL)	0.25	0.05	O,D
Tokyo	SOR-Ring(ISSP)	0.38	0.11	O,D
Okazaki	UVSOR (IMS)	0.75	0.43	O,D
Sweden				
Lund	MAX (MAX)	0.55	0.31	O,D
Taiwan				
Hsinchu	SRRC(SRRC)	1.3	1.4	C,D
UK				
Darsbury	SRS	2.0	3.2	O,D
USA				
Gaithersburg,MD	SURF(NBS)	0.284	0.6	O,D
Ithica,NY	CESR(CHESS)	5.44	11.2	O,PD
Stanford,CA	SPEAR(SSRL)	3.5	7.4	O,D
	PEP (SSRL)	7.0-14.5	41.0 (14.GeV)	O,PD
Stoughton, WI	Tantalus (SRC)	0.24	0.05	I,D
	Aladdin (SRC)	1.0	1.07	O,D
Upton, NY	NSLS VUV (BNL)	0.75	0.49	O,D
	NSLS x ray(BNL)	2.5	5.0	O,D
Berkeley, CA	ALS (LBL)	1.5	1.5	C,D
Argonne, IL	APS (ANL)	7.0	19.0	C,D
USSR				
Karkhov	N-100 (KPI)	0.10	0.04	O,D
MOSCOW	PLAMIA I	0.45	0.2	C,D
Novosibirsk	VEPP-2M(INP)	0.67	0.54	O,PD
	VEPP-3 (INP)	2.2	4.3	O,PD
	VEPP-4 (INP)	7.0	46.0	O,Par

49 F019B PHOTON FACTORY Japan (in operation)

Nationa Laboratory for High Energy Physics, Oho 1-1 , Tsukuba-shi, Ibarakl-ken, 305 Japan. Tel:0298-64-1171. Director: Jun-ichi Chikawa.

The Photon Factory is a storage ring; beam first obtained in March 1982.

Operational data (for Sept 1987 to March 1988): User experiments 2884 h, machine study 726h; Typical operation 24 h/day, 11 days/2weeks. In-house staff consists of 64 scientists, 2 students, 25 technicians, and 5 administrators.

Experimental Activities: Active proposals 356; solid state/materials 170; biology/biochem.53; chemisty/atom.mol. phys. 82; medicine 12; technology/industrial 21; each science 8; others 10.

Typical user beam characteristics.

	1	2
Lattice Name	FODO	FODO
Particle	Electron	Positron
Energy (GeV)	2.5	2.5
No.of Bunches	312	312
Initial current(mA)	300	250
Average current(mA)	195	174
Lifetime (h) 200 mA	15	30
Emittance (nmrad)H/V	130/2.3	130/2.3
Bunch duration(ns)	2σ = 0.1	2σ = 0. 1

General Ring Parameters.

Injector: Linac Energy: 2.5 GeV
cycle: 25 Hz orbiit period:620 ns
Bending radius: 8.66 m
rf: 500 MHz
MAX energy: 3.0 GeV (at 1mA) Max current: 520 mA (at 2.0 GeV)

50 F019C TRISTAN AR Japan (in operation)

National Laboratory for High Energy Physics, Oho 1-1, Tsukuba-shi, Iabarki-ken, 305 Japan. Tel: 0298-64-1171.
Director: Jun-ichi Chikawa.
The Tristan AR is a storge ring.
Operational Data (For April 1987 to March 1988). User experiments 1799h (parasitic). Typical operation 24/day7 days/week. In-house staff consists of 4 dedicated and14 part time scientist, 1 part time engineer, and 2 parttime technicians.
Experimental Activities: Solid State/materials 8; medicine 4; earth science 2.

Typical user beam characteristics.

	1
Lattice name	FODO
Particle	Electron
Energy (GeV)	5.8-6.5
No.of Bunches	1
Initial current (mA)	20
Average Cunent (mA)	10
Lifetime (h) 5 mA	1
Emittance (nmrad) H/V	250/ -
Bunch duration (ns)	2σ = 0.I

General ring parameters

Injector: Linac
Energy: 2.5 GeV Cycle: 25 Hz
Orbit Period: 1250 ns
Bending Radius: 23.2 m rf: 508.58 MHz
MAX energy: 8.0 GeV (at 25mA)
Max. Current: 30 mA (at 6GeV)

51 F019D SOR-RING Japan (in operation)

Synchrotron Radiation Laboratory, Institute for Solid State Physics, University of Tokyo, 3-2-1 Midori-cho,Tanashi-shi, Tokyo 188, Japan. Tel: 0424-61-4131, ext.328. Director: T. Ishii. The SOR-RING is a storage ring; beam first obtained in Dec. 1974.

Operational data (for April 1987 to March 1988). User experiments 1300h; machine study 100h. Typical operation10h/day, 4.5 days/week. In-house staff consists of 9 scientists, 4 students, 4 technicians, and 1 administrator.

Experimental activities: Active proposals 32; solid Solid state/materials 24; biology/biochemistry 4;technology 1; others 3.

Typical user beam characteristics.

Lattice name	
Particle	Electron
Energy (GeV)	0.38
No. of bunches	7
Initial current (mA)	200-300
Averge current (mA)	150
Lifetime (h)200 mA	240 min
Emittance(nmrad)H/V	300
Bunch duration (ns)	0.65

General Ring Parameters.

Injector: Synchrotron
Energy: 0.308 GeV Cycle: 1 Hz
Orbit period: 57.9 ns
Bending Radius: 1.1m rf: 120.83 MHz
Max energy: 0.38 GeV
Max. current: 510 mA (at 0.308 GeV)

52 F019E UVSOR Japan (in operation)

Institute for Molecular Science, Myodaui, Okazaki 444, Japan. Tel: 0561-54-1111,(ex. 400-409).
Director: Katsumi Kimura.
The UVSOR is a storage ring; first beam obtained in Nov. 1983.

Operational data (for April 1987 to March 1988). User experiments 1800 h; machine study 450 h. Typicaloperation 10 h/day, 5 days/week. In-house staff consistsof 5 scientists, 2 engineers, 4 technicians, and 1 administrator.

Experimental activities: Active proposals 120; solid state/materials 53%; biology/biochem 2%; chemistry/atom. mol. phys. 30%; technology/industrial 13%; others 2%.

Typical user beam characteristics.

	1	2
Lattice name	---	---
Particle	Electron	Electron
Energy (GeV)	0.75	0.75
No.of bunches	16	1
Initial current (mA)	100	10
Average Current (mA)	60	6
Lifetime(h) 100 mA	3	5
Emittance (nmrad)H/V	< 160	<160
Bunch duration (ns)	0.4	0.4

General ring parameters.

Injector: Synchrotron
Energy: 0.6 GeV Cycle: 2.5 Hz
Orbit Period: 177.6 ns
Bending radius: 2.2 m rf: 90.115 MHz
Max energy: 0.8 GeV
Max. current: 500 mA at 0.6 GeV

58 F022B This article discusses pulse radiolysis using synchrotron radiation from the TRISTAN accelerators, the accumulation ring (AR) and the main ring (MR) . They provide intense radiation, the energy of which goes up to the y-ray region, and a pulse length below 50 ps, which could be below 10 ps. The time separation between neighboring bunches is 1.25 us at the AR and 5 us at the MR. These features should make it possible to detect reactive intermediates in radiation-induced reactions in the time span from picoseconds to microseconds. Possible applications of the picosecond synchrotron radiation pulse radiolysis are introduced. They include studies of radiation effect on resist materials, on radiation sensitive materials, biological systems, and reaction from selected states such as Rydberg state, inner-shell excited states, and multi-ionized states.

APPLICATIONS

Picosecond SR pulse radiolysis is a new, powerful method, and will be used in a very wide field. Here, several possible applications are picked up.

A. Radiation effects on resist materials for x-ray lithography

A number of papers have been published on radiolysis of resist materials using Co y rays (1.17 MeV, 1.33 MeV). The short-lived intermediates have been studied by electron pulse radiolysis. In the actual field of x-ray lithography, however, x rays of several kiloelectron volts are used. Now we can directly study the short-lived species to clear the reaction mechanisms by using picosecond SR pulse radiolysis.

23 F011B SOR RING PROJECTS

COMPANY	DEVELOPMENT STAGE
NTT	UNDER CONSTRUCTION
HITACHI	UNDER CONSTRUCTION
TOSHIBA	UNDER CONSTRUCTION
MITSUBISHI	UNDER CONSTRUCTION
ELECTRO-TECHNICAL LAB	UNDER DEVELOPMENT
RESEARCH & DEVELOPMENT CORP.	UNDER DEVELOPMENT
SORTEC CONSORTIUM	PLANNING

FURTHERMORE, SEVERAL JAPANESE MANUFACTURERS AREDEVELOPING VERTICAL STAGE X-RAY STEPPERS FOR SYNCHRONTRONWORK.

75 F032E Sortec

[illegible]

Sortec is a joint venture between the government and 13private companies formed to promote the development offabrication technologies for ULSI chips with capacitiesof 64 megabits or more. Among its participants is theMITI-backed Key Technology R&D Promotion Center. Sortecset up SORTEC-1 at its Tsukuba Research Institute inApril 1989. The facility consists of a small linearaccelerator, an electron acceleration ring 15 meters indiameter, and an electron accumulation ring 15 meters indiameter. It first succeeded in generating SOR in August1989. Sortec planned to invest a total of 14.3 billionyen (nearly $100 million) over ten years beginning in
1986 and has already spent 3 billion yen (over $20million) on construction of the Tsukuba ResearchInstitute and 4 billion yen (nearly $28 million) on theSOR facility.

NAME OF FACILITY	SORTEC-1
ORGANIZATION	SORTEC, ELECTROTECHNICAL LAB
ELECTRON ENERGY (GeV)	1.0
ORBITAL RADIUS (m)	2.78
WAVELENGHTH (nm)	1.55
INJECTION METHOD	SYNCHROTRON
INJECTION ENERGY (MeV)	1000
MAGNET	NORMAL CONDUCTING
SIZE	15m
STATUS	OPERATIONAL 8/89

66 F029A Sortec Corp. has develope a Y3 billion synchrotron orbital radiation (SOR) light source system for lithographing microcircuits on next-generation 64-megabit semiconductors. In March, the firm began trial operations of the system at its laboratory in Tsukuba, northeast of Tokyo.

Nippon Telegraph and Telephone Corp. has tentatively built a similar system, but Sortec's SOR can process 20-30 wafers an hour, effectively the largest output in the world. The company hopes to develop the penpherial equipment for mass-producing next-generation semiconductors by the end of next February.

Current lithography techniques based on ultraviolet rays may not be suitable for production of next-generation semiconductor because such chips need shorter-wavelength X-rays for the lithographing process. Industrial sources say the SOR system is expected to be the leading technology in develop mass-production facilities next-generation semiconductors, even though an X-ray laser lithography system is already under development.

The SOR system rotates electrons in a vacuum ring at a speed approaching that of light, and emits strongly directive X-rays by means of deflection magnet inside the ring.

Sortec, capitalized at 1.28 billion, was established in June 19866 as a joint venture between the Japan Key Technology Center and 13 electronics makers, including Toshiba Corp, Hitachi, LTD., Mitsubisi Electric Corp., NEC Corp., and Fujitsu Ltd. The Japan Key Technology Centerr, set up in October 1985, is funded by profits from the public sale of NTT shares.

31 F015A A study of high beam current storage at a low energy is being conducted on the compact electron storage ring NIJI-1. In general, it is said that the stored beam liftime is rapidly shortened as the beam energy

decreases, and the high beam current storage is difficult to obtain. However, a stored beam current above a 350 mA was obtained at an injection energy of 100 MeV, and the lifetime of the stored beam is considerably long. For example, e-folding liftime is about 2h at 100 MeV. In this paper, we estimate the beam current decay rate due to the residual gas scattering, the ion trapping effect, and the Touschek effect, and make clear these contributions to the beam liftime. It was clear that the Touschek liftime is lengthened according to the bunch size growth, which is roughly explained by the longitutinal coupled bunch instability.

15 F008B In the work reported here, we estimate the design parameters of a superconductive synchrotron radiation (SR) ring employing the electron undulating method, which is capable of large-area exposure of SR. The optimum electron energy is found to lie in the range 0.6 to 0.7 GeV with a magnetic field of 4.0T to 4.5T and a beam current in the range 200 to 300mA. Research into the miniaturization of the SR ring and its injector to complete a practical SR system has continued. In particular, low/energy injection improves the cost effectiveness of the SR system, but this requires further study. Therefore, the Electrotechnical Laboratory (ETL) of the Japanese Ministry of International Trade and Industry and Sumitomo Electric Industries, Ltd., jointly completed "NIJI-I ," the firsT compact normal-conductive SR ring in the world designed for low/energy injection studies. we succeeded in making the first beam storage in February 1986 and since then have achieved the storage of a beam current of more than 200 mA of 163-MeV electrons; its 1/e lifetime was about 50 min. Research on topics such as high efficiency injection at low/ energy and miniaturization of the injector is continuing.

22 F011A Sumitomo Heavy Industries has started construction on acompact superconducting electron storage ring for X-raylithography, which is scheduled for completion nextspring.

73 F032C Sumitomo Heavy Industries

Sumitomo Heavy Industries has developed a SOR facilitycalled AURORA, which utilizes a superconducting magnet,and has begun to market it as an X-ray source for thefabrication of ULSI chips with memory capacities of 64megabits. It consists of a linear accelerator, a3-meter-diameter, accumulation ring, and a light beamline and is able to create line widths of 0.2 to 0.3 micron. The company is reported to have been working ondevelopment of the compact facility for the past four years and is marketing it at about 3 billion yen perunit.

NAME OF FACILITY	AURORA
ORGANIZATION	SUMITOMO HEAVY INDUSTRIES
ELECTRON ENERGY (GeV)	0.65
ORBITAL RADIUS (m)	0.5
WAVELENGTH (nm)	1.02
INJECTION METHOD	MICROTRON
INJECTION ENERGY (MeV)	150
MAGNET	SUPERCONDUCTING
SIZE	3.7x1.1m
STATUS	OPERATIONAL 8/89

34 F016C

69 F031A SUMITOMO HEAVY INDUSTRIES , LTD. SAID FRIDAY IT HAS COMPLETED THE WORLD'S SMALLEST MACHINE PRODUCING X-RAY BEAMS FOR USE IN MAKING COMPUTER MICROCHIPS WITH MEMORIES OF OVER 64 MEGABITS. THE MACHINE IS DESIGNED TO PRODUCE SYNCHROTRON ORBITAL RADIATION (SOR), A TYPE OF LIGHT GENERATED WHEN A STRING OF ELECTRONS ACCELERATED CLOSE TO THE SPEED OF LIGHT IS BENT BY A MAGNETIC FIELD. THE SOR MACHINE IS EXPECTED TO BE USED IN NEXT-GENERATION ETCHING TECHNOLOGY CALLED X-RAY LITHOGRAPHY FOR ULTRA-FINE CIRCUITS. MEASURIN@ ONLY ONE METER IN DIAMETER, THE SOR MACHINE IS THE SMALLEST IN THE WORLD, THE FIRM SAID. THE TECHNOLO@Y IS BELIEVED VITAL FOR MAKING CHIPS WITH MORE THAN 64 MEGABITS OF MEMORY. THE MOST ADVVANCED SEMICONDUCTORDS OR CHIPS CURRENTLY BEING MASS PRODUCED HAVE FOUR-MEGABIT MEMORIES. AT PRESENT, PHOTO-LITHOGRAPHY USING ULTRAVIOLET LIGHT IS USED MAINLY TO FABRICATE FINELY DETAILED STRUCTURES IN MICROCHIPS. BUT RAYS WITH SHORTER WAVE LENGTHS, SUCH AS LASERS AND X-RAYS, ARE NECESSARY FOR EVEN SMALLER-SCALE GEOMETRICS IN VERY LARGE-SCALE INTEGRATED (VLSI) CIRCUITS.

SUMITOMO HEAVY INDUSTRIES SAID IT HAS SUCCEEDED IN EXTRACTING SYNCHROTRON ORBITAL RADIATION FROM A STORAGE RING WITH A SUPERCONDUCTING MAGNET TO BEND A STREAM OF ELECTRONS. MORE THAN 17 SOR RINGS ARE CURRENTLY USED IN JAPAN, BUT A MAJORITY OF THEM ARE QUITE LARGE MACHINES WITH THEIR PRINCIPAL PURPOSES BEING ACADEMIC RESEARCH, ACCORDING TO DATAQUEST JAPAN, A COMPANY SPECIALIZING IN SURVEYING THE COMPUTER INDUSTRY.

FIVE DOMESTIC AND OVERSEAS LABORATORIES, INCLUDING THOISE OF SUMITOMO HEAVY INDUSTRIES AND NIPPON TELEGRAPH AND TELEPHONE CORP. (NTT), ARE DEVELOPING COMPACT SOR RINGS DESIGNED FOR VLSI PRODUCTION, ACCORDING TO THE COMPANY. SUMITOMO, HOWEVER , SAYS IT IS THE ONLY COMPANY THAT HAS VIRTUALLY COMPLETED THE OVERALL STRUCTURE PROCESSING SYSTEM FOR OVER 64-MAGABIT MEMORY CHIPS USING THE SOR RING. IT PLANS TO START IN 1991 SELLING THE SOR MACHINE, DUBBED AURORA, WITH PRICE TAGS OF 2.5 BILLION YEN FOR THE MAIN BODY AND 70 TO 80 MILLION YEN FOR THE PERIPHERAL EQUIPMENT.

19 F009B The compact, superconducting synchrontron called "Aurora"is remakably small, although it does weigh 20 metrictons. The synchrotron is encased in iron to provide thecorrect magnetic field profile from the superconductingmagnets, not much radiation shielding is needed. Concretewalls 1 foot thick are sufficient, so construction costdshould be small. Assuming there are no unexpectedproblems it will cost about $15 million (plus about$500,000 for each beamline) and ahould be ready fordelivery in two years. The steady state total power isonly 250kW.

59 F023A SUBJ : NEW TYPE OF RADIATION PRODUCED BY RESEARCHERS

SOURCE : TOKYO THE DAILY YOMIURI IN ENGLISH 8 OCT 89 p2

RESEARCHERS AT TOHOKU UNIVERSITY IN MIYAGI-KEN HAVE SUCCEEDED IN PRODUCING ELECTROMAGNETIC RADIATION A MILLION TIMES STRONGER THAN THAT PREVIOUSLY PRODUCED IN ALINEAR ACCELERATOR.

RESEARCHERS AT THE NUCLEAR FACULTY LABORATORY AT THE UNIVERSITY SAID FRIDAY THE "NEW" WAVES THEY HAD PRODUCED,"COHERENT SYNCHROTRON RADIATION," COULD HAVE A VARIETY OF PRACTICAL APPLICATIONS. THEY SAID THEY PRODUCED THE RADIATION WITH THE FACILITY'S LINEAR ACCELERATOR, WHICHHAS A 300 MILLION ELECTRON

VOLT (EV) CAPACITY. TOSHIHARU NAKAZATO, AN ASSISTANT AT THE UNIVERSITY INCHARGE OF THE EXPERIMENT, SAID THAT THE TOHOKU RESULTS WOULD BE EASILY REPRODUCIBLE AT OTHER FACILITIES. HE SAIDTHE BREAKTHROUGH COULD HAVE AN IMPACT NOT ONLY ON VARIOUS BASIC SCIENCES INCLUDING PHYSICS, CHEMISTRY, BIOLOGY, MEDICINE, AND ENGINEERING, BUT ALSO ON VARIOUS INDUSTRIESIN THE FUTURE.

SYNCHROTRON RADIATION IS AN ELECTROMAGNETIC WAVE PRODUCEDWHEN THE COURSE OF AN ELECTRON IS BENT BY A MAGNETIC FIELD. SYNCHROTRON RADIATION CAN BE PRODUCED BY VARIOUS KINDS OF ACCELERATORS. HOWEVER, THE SYNCHROTRON RADIATION PRODUCED BY A SYNCHROTRON, A CIRCULAR ACCELERATOR, CAN INCLUDE RAYS OF FREQUENCIES RANGING FROMULTRAVIOLET TO INFRARED, WHICH MAY HAVE WIDERAPPLICATION.

TO PRODUCE THE STRONGER RADIATIONS, THE TOHOKU UNIVERSITY RESEARCHERS EMPLOYED WHAT THEY CALL A "BUNCH METHOD,"INWHICH THEY GROUPED UP TO A MILLION ELECTRONS TOGETHER TOFORM A "BUNCH" TWO MILLIMETERS IN DIAMETER; ALLOWING THE PRODUCTION OF THE STRONG SYNCHROTRON RADIATION. TAKIOTOMIMASU, OF THE ELECTROTECHNIAL LABORATORY AT THE AGENCYOF INDUSTRIAL, SCIENCE AND TECHNOLOGY, SAID THEPOSSIBILITY OF COHERENT SYNCHROTRON RADIATION HAD BEEN SHOWN MANY YEARS AGO THEORETIALLY, BUT EXPERIMENTS HAD NOT PRODUCED THE RADIATION BECAUSE THE MEASUREMENT TECHNOLOGY WAS INSUFFICIENT.

GREAT IMPROVEMENTS IN THE MEASUREMENT TECHNOLOCY RESULTEDIN THE TOHOKU UNIVERSITY'S GREAT FINDING, ACCORDING TOTOMIMASU, THE HEAD OF THE QUANTUMRADIATION DIVISION OF THE INSTITUTE. HOWEVER, THE SHORTEST FREQUENCY OF THERAYS PRODUCED IN THE EXPERIMENT WAS 0.3 MILLIMETERS. SUCH RAYS ARE OF NO USE FOR MEDICAL OR BASIC PHYSICAL STUDIES.

TOMIMATSU SAID THAT TO APPLY THE RAYS FOR PRACTICAL USE,RAYS OF 0.1-0.01 MILLIMETERS FREQUENCY WOULD BENECESSARY.

3 F0000

X-RAY MASK TECHNOLOGIES

X-ray masks are all made by E-beam mask writers and the feature size is limited by the writer capability. Most mask writers can accommodate 0.5 um feature size but only four (IBM, Hitachi, JEOL and ASM) can handle 0.25 um geometry or smaller. The others are limited from the standpoint of either performance or cost. Vector scan systems are much to slow while raster scan systems are performance limited. Variable aperture systems appear to show the most promise.

Mask technology is also limited by inspection techniques and repair systems. Current inspection is inadequate for 0.5 um feature size and defect detection sensitivity of optical inspection systems is to poor, while E-beam systems are too slow. Mask repair techniques are being developed for 0.25 um feature sizes and should be commercially available soon.

There are four principle mask materials (technologies): Boron Nitride, Silicon Nitride, Silicon and Silicon Carbide.

Boron Nitride (BN)

This technology is adequate for 0.5 um geometry with appropriate consideration for distortion and lifetime. Most distortion measurements have been made on masks that use a gold absorber to define the pattern. Greater distortion occurs on subtractively processed (as opposed to additively processed) masks. Defects, however, are a greater problem in additive processing, but can be

managed with critical inspection and repair procedures. Lifetime can be increased by changing membrane materials. Those produced by LPCVD using diborane and ammonia suffer more damage from X-ray doses than those made from borazine. Additional research can make this technology adequate for synchrotron-radiation dosage levels.

Silicon Nitride (Si2N4)

This technology has been used successfuly with either gold or tungsten as the absorber. It is much more resistant to high radiation doses that BN, but distortion characteristics are similar to BN, and defect levels are the same. There have been past difficuties with consistancy in mass production.

Silicon (Si)

While this technology has a modulus of elasticity similar to BN and Si2n4, it is 100 times more resistant to the effects of synchrotron radiation. Its visible-wavelength transmission properties, however, limit its usefulness with presently available alignment optics. It has been used with both gold and tungsten absorber materials and will probably replace the other two technologies. Future masks may use silicon for both the membrane and the absorber.

Silicon Carbide (SiC)

This technology may be best because of its superior mechanical strength, good visible-light and X-ray transmission properties. Made with a tungsten absorber, these masks have better distortion and stability characteristics than boron nitride or silicon nitride products.

40 F016I
29 F014B Poly (phenyl methacrylate) (PPhMA) is utilized as a base resist of radiation-induced graft copolyerization for the purpose of high-throughput x-ray lithography. PPhMA has dry-etching resistance due to the aromatic ring in its side chain and, therefore, it can be used for large-scale integration (LSI) fabrication. Gaseous acrylic acid is graned into PPhMA film to produce a copolymer which is insoluble in the solvent of PPhMA. The graft processing enhances the resist sensitivity by three orders of magnitude to the level of 10 mJ/cm^2. The swelling of the grafted resist during development is drastically minimized by formation of a cross-linked structure in the grafted resist by thennal dehydration of acrylic acids. The above technique successfully provided a negative patten with feature size down to 0.3 um.

The x-ray mask used here comprises a hybrid film of boron nitride (2 um thickness) and polyimide (3 um thickness) as a substrate membrane and gold pattern (1 um thickness) as an absorber.

42 F016K
79 F033B X-Ray Mask Using W-Ti Alloy Absorber

By using this low-stress W-Ti film as absorber, we have manufatured the X-ray mask to be used in the current

1M DRAM test manufacture. The mask substrate used has been that which was developed for the SX-5 use, measuring 3 inches in outer diameter and 25 x 25 mm^2 in wind size, and comprising an SiN (2 um)/polyimide (1 um) membrane. The position distortion of this mask has been about 0.1 um maximum as a result of measurement using the Nikon-made Model 2-1 lightwave inteference type coordinate measuring instrument. This value is small enough for manufacturing the 1M DRAM.

61 F025A An electron-beam inspection system with a capability ofdetecting quarter-micron defects has been developed andis applied to the inspection of the x-ray mask itself. The accuracy of this system is measured and discussed. The distortion of the electron-beam deflection is 0.08um(root-mean-square error) within 70 x 90 um area in thescan field of 100 um^2. A sample x-ray mask has Auabsorption patterns with the thickness of 0.8um on a 2.0um-thick SiN membrane. An accelerating voltage of 3kV was found to give a stable signal with a minimum ofcharging effects. The inspection is performed by meansof die-to-die comparison scheme. Detection of 0.3umdefects was demonstrated, indicating the potential of electron-beam technology for x-ray mask inspection.

27 F013C A prototype synchrotron radiation (SR) stepper Sor quarter-micron devices has been developed and installed at the Photon Factory in the National Laboratory for High Energy Physics, Japan. The stepper features are, (i) exposure in an atmospheric environment, (ii) large exposure area (25-mm sq), and (iii) alignment error detection at all times, including during exposure. The stepper consists of an SR extracting chamber, precision mechanical stages, and an alignment error detection system. An SR beam in UHV goes through a beryllium window into an atmospheric environment, and covers the 25-mm sq exposure area by using an oscillating mirror. Patterns on a mask are imprinted onto a wafer. Mask and wafer are, respectively, held in place with vacuum chucks. Their subsequent positioning movements are driven in 6 degrees of freedom by piezoelectric actuators for fine alignment and gap setting. The alignment system, based on the previous Fresnel lens optical system, newly employs a di@erential mode linear Fresnel zone plate alignment method. As the optical system for this method is located at the outside ofan SR beam, it can detect an alignment error between a mask and a wafer at all times, including during exposure. Patterns measuring 0.2um were completely successfully imprinted on a wafer. Until now, 0.03-um (3o) positioning accuracy and 0.2um (3o) overlay accuracy were achieved.

53 F020A A new method for pattern reduction in the x-ray region is proposed. In its principle was used the asymmetric Bragg reflection giving the different beamwidth in the reflected beam from the incident one. Light from an undulator line (BL-2) at the Photon Factory was used to obtain highly spatially resolved replication in reasonably short exposure time. Performed was one dimensional demagnification of a pattern with a ratio of 1/4 in the following condition: Si 111 reflection was used where the offset angle alpha from the surface is 22 deg and the wavelength lambda was 3.5 lambda, which is available from the 7th harmonic of the undulator radiation. The

submicron scale resist pattern was resolved.

17 F008D In the work reported here, we estimate the design parameters of a superconductive synchrotron radiation (SR) ring employing the electron undulating method, which is capable of large-area exposure of SR. The optimum electron energy is found to lie in the range 0.6 to 0.7 GeV with a magnetic field of 4.0T to 4.5T and a beam current in the range 200 to 300mA. Research into the miniaturization of the SR ring and its injector to complete a practical SR system has continued. In particular, low/energy injection improves the cost effectiveness of the SR system, but this requires further study. Therefore, the Electrotechnical Laboratory (ETL) of the Japanese Ministry of International Trade and Industry and Sumitomo Electric Industries, Ltd., jointly completed "NIJI-1 ," the firsT compact normal-conductive SR ring in the world designed for low/energy injection studies. we succeeded in making the first beam storage in February 1986 and since then have achieved the storage of a beam current of more than 200 mA of 163-MeV electrons; its 1/e lifetime was about 50 min. Research on topics such as high efficiency injection at low/ energy and miniaturization of the injector is continuing.

41 F016J

60 F024A Toppan Printing Co. has doubled mask prodution capacity masks used for masking next generation integrated circuit chips including 4 megabit dynamic random access memory Chips.
The firm has built a plant specializing in production of such masks at a factory in Saitama prefecture. Plant operations have already begun, said spokesman.

4 F0000

X-RAY RESIST TECHNOLOGY

X-ray resists must satisfy contradictory requirements. High sensitivity to ionizing radiation is necessary for exposure speed, while good etch resistance in plasma environments is required after exposure. For conventional (tube) an pulsed plasma sources, very low X-ray fluxes require extremely sensitive resists, while with synchrotron sources, conventional elelctron or photoresists can be used. Four approaches have been used to formulate X-ray resists with higher sensitivities:

1. incorporation of more highly absorbing groups
2. use of more reactive groups
3. use of higher molecular weight polymers
4. new formulations which exhibit amplification in the exposure or development steps

All four are incorporated in DCOPA that operates as a negative resist. It is generally used with tri-level processing, and has a sensitivity of 14 mJ/cm^2 and a resolution of 0.5 um. The limit of resolution is due to swelling during development, however, it must be exposed in a .3% oxygen in nitrogen ambient for optimum resolution.

Another negative resist, called PSTTF, has a sensitivity of 50 mJ/cm^2 and 0.5 um resolution, and show reduced swelling, would be suitable for the X-ray output of plasma sources, but is still to slow for electron-impact sources.

Positive resists require longer exposure times, but one is

available with a sensitivity of 10 mJ/cm^2 and resolution of 0.5 um. Generally the positive resists have low sensitivity but can obtain excellent resolution with plasma or synchrotron sources.

28 F014A Poly (phenyl methacrylate) (PPhMA) is utilized as a base resist of radiation-induced graft copolyerization for the purpose of high-throughput x-ray lithography. PPhMA has dry-etching resistance due to the aromatic ring in its side chain and, therefore, it can be used for large-scale integration (LSI) fabrication. Gaseous acrylic acid is graned into PPhMA film to produce a copolymer which is insoluble in the solvent of PPhMA. The graft processing enhances the resist sensitivity by three orders of magnitude to the level of 10 mJ/cm^2. The swelling of the grafted resist during development is drastically minimized by formation of a cross-linked structure in the grafted resist by thennal dehydration of acrylic acids. The above technique successfully provided a negative patten with feature size down to 0.3 um.

A. Resist materials

PPhMA was obtained from Daikin Co. Ltd. Its molecular weight and molecular weight distribution 2. 1 X 10^5 and 2.5, respectively. The resist sample was prepared by dissolving tbe polymer in 2-methoxyethylacetate to make a solution with weight concentration of 12%.

55 F021A Soft x-ray absorption spectra and spectral sensitivity of x-ray resists are studied by using synchrotron radiation. Spectral sensitivity is successfully evaluated from the fragment yield change of the decomposed resists by changing incident x-ray wavelengths. This evaluation method is newly developed here. Using this technique, x-ray wavelength dependency for the decomposition efficiency of polymer resists poly (2-methylpentene- 1 -sulfone) and their decomposition characteristics are clarified. These are very important for development of more x-ray resists.

80 F032C Positive X-Ray Resist XPB

The X-ray resist is required to have a high sensitivity, a high resolution and a high dry-etching resistance. The novolac resist can be expected to meet these requirements. In the current 1M DRAM test manufacture, we have used a novolac positive X-ray resist named XPB, whose sensitizer is Poly (2-methyl-1 -pentene sulfone), and resin is cresol novolac. This resist has been experimentaly synthesized by Japan Synthetic Rubber Co., Ltd.(JSR). The sensitizer and the resin are in the ratio 1:10, and the developer used was a 3.4 wt. percent solution of tetrmethyl ammonium hydmxide (TMAH). For a comparison, meanwhile, we have also examined the negative X-ray resist CPMS (JSR-made "MES-X") and the positive eletron beam resist EBR-9 HS (Toray-made), which is referred to as high-performance resists. Figure 3 (not shown) shows the remaining film ratio curves of the three resists. It proves that the sensitivity of the XPB is lower than that of the CPMS, but is about the same as that of the EBR-9 HS, which is referred to as a high-sensitivity positive resist. The XPB's contrast is higher than the EBR-9 HS's. Meanwhile, we have also confirmed that the dry-etching resistance of the XPB is about the same as that of the

resistance of the XPB is about the same as that of the positive photoresist which is actully being used in manufacturing VLSI, such as the AZ- 1350 and the OFPR-800. As shown above, the XPB has outstanding performance as an X-ray resist.

43 F016L X-Ray Photoresist

By the advent of SOR, requirements for the sensitivity of the X-ray photoresist have been slackened, but when considering the practical use of SOR lithography, the development of X-ray photoresists is indispensable. They must have an 0.1 um level resolution and adequate dry-etching resistance. In addition, they are required to have a high sensitivity of <100 mJ/cm^2. Further development is necessary for both the positive and the negative photoresists. Further, it is important that the photoresists do not spread.

54 F020B A new method for pattern reduction in the x-ray region is proposed. In its principle was used the asymmetric Bragg reflection giving the different beamwidth in the reflected beam from the incident one. Light from an undulator line (BL-2) at the Photon Factory was used to obtain highly spatially resolved replication in reasonably short exposure time. Performed was one dimensional demagnification of a pattern with a ratio of 1/4 in the following condition: Si 111 reflection was used where the offset angle alpha from the surface is 22 deg and the wavelength lambda was 3.5 lambda, which is available from the 7th harmonic of the undulator radiation. The submicron scale resist pattern was resolved.

16 F008C In the work reported here, we estimate the design parameters of a superconductive synchrotron radiation (SR) ring employing the electron undulating method, which is capable of large-area exposure of SR. The optimum electron energy is found to lie in the range 0.6 to 0.7 GeV with a magnetic field of 4.0T to 4.5T and a beam current in the range 200 to 300mA. Research into the miniaturization of the SR ring and its injector to complete a practical SR system has continued. In particular, low/energy injection improves the cost effectiveness of the SR system, but this requires further study. Therefore, the Electrotechnical Laboratory (ETL) of the Japanese Ministry of International Trade and Industry and Sumitomo Electric Industries, Ltd., jointly completed "NIJI-1 ," the firsT compact normal-conductive SR ring in the world designed for low/energy injection studies. we succeeded in making the first beam storage in February 1986 and since then have achieved the storage of a beam current of more than 200 mA of 163-MeV electrons; its 1/e lifetime was about 50 min. Research on topics such as high efficiency injection at low/ energy and miniaturization of the injector is continuing.

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX G

E-BEAM LITHOGRAPHY (EBL)

0701050A01 - EBL - SYSTEM PERFORMANCE

0701050C01 - E-BEAM RESISTS

Page No. 1
04/02/90

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: E-BEAM LITHOGRAPHY

CTL #	SHEET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: ELECTRON BEAM LITHOGRAPHY (EBL)								
07010 50AC1	A	BL		B	G0000		Y	
07010 50A01	A	JA	B	P	G008A	P	Y	ELECTROTECHNICAL LABORATORY
07010 50A01	A	JA	E	P	G001B	P	Y	FUJITSU LTD
07010 50A01	A	JA	B	P	G010A	P	Y	FUJITSU LTD.
07010 50A01	A	JA	A	P	G012A	P	N	HITACHI LTD., CENTRAL REASEARCH LABORATORY
07010 50A01	A	JA	A	P	G013A	P	Y	JOEL
07010 50A01	A	JA	A	S	G003A	G013A	Y	JOEL LTD.
07010 50A01	A	JA	A	P	G005A	P	Y	NTT LABORATORIES
07010 50A01	A	JA	B	P	G004A	P	Y	TOSHIBA CORPORATION, ULSI RESEARCH CENTER
07010 50A01	A	JA	B	P	G011A	P	Y	TOSHIBA CORPORATION, ULSI RESEARCH CENTER
07010 50A01	A	JA	B	S	G009A	G004A	Y	TOSHIBA CORPORATION, VLSI RESEARCH CENTER
** *** SUB-TECHNOLOGY: E-BEAM RESISTS								
07010 50C01	A	BL		B	G0000		Y	
07010 50C01	A	JA	A	P	G006A	P	Y	HITACHI LTD., CENTRAL RESEARCH LABORATORY
07010 50C01	A	JA	A	S	G013B	G003B	Y	JOEL

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04/02/90

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: E-BEAM LITHOGRAPHY

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
07010 50C01	A	JA	A	P	G003B	P	Y	JOEL LTD.
07010 50C01	A	JA	C	P	G006A	P	Y	NEC CORPORATION, FUNDAMENTAL RESEARCH LABORATORIES
07010 50C01	A	JA	C	P	G005B	P	Y	NTT LABORATORIES
07010 50C01	A	JA	B	P	G009B	P	Y	TOSHIBA CORPORATION, VLSI RESEARCH CENTER

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: E-BEAM LITHOGRAPHY

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ################### SUB-TECHNOLOGY: ELECTRON BEAM LITHOGRAPHY (EBL)							
07010 50A01 A EBL	MINIMUM FEATURE SIZE --- MICRONS (um) --- IMPR. DIR: L	LINE EDGE ROUGHNESS --- MICRONS (um) --- IMPR. DIR: L	FIELD BUTTING ERROR --- MICRONS (um) --- IMPR. DIR: L	OVERLAY ACCURACY --- MICRONS (um) --- IMPR. DIR: L	DIMENSIONAL ACCURACY --- MICRONS (um) --- IMPR. DIR: L	THROUGHPUT --- QTY OF 100mm WAFERS/HR --- IMPR. DIR: H	SYS PERF
** ################### SUB-TECHNOLOGY: E-BEAM RESISTS							
07010 50C01 A EBL	SENSITIVITY --- uC/cm^2 --- IMPR. DIR: L	RESOLUTION --- MICRON (uM) --- IMPR. DIR: L	TECHNOLOGY NAME --- NONE --- IMPR. DIR: X	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	MATL

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JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: E-BEAM LITHOGRAPHY

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: ELECTRON BEAM LITHOGRAPHY (EBL)												
07010 50A01 A EBL 11	B	ELECTROTECHNICAL LABORATORY ---- 1-1-4 UMEZONO, SAKURA-MURA, NIIGHARI-GUN, IBARAKI 305, JAPAN ---- SHIGEO OKAYAMA ----	---- ---- ----	---- ---- ----	Y A DT U	0.4 ---- SEE MEMO	----	----	----	----	----	JDY/VOL 6 # 1/0199 02/01/8 8 G008A / / JA
07010 50A01 A EBL 3	E	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	----	----	----	JAA/VOL 3 #6/008 06/30/8 8 G001B / / JA
07010 50A01 A EBL 14	B	FUJITSU LTD. ---- 1015 KAMIODANAKA, NAKAHARA-KU, KAWASAKI 211, JAPAN ---- S.HAMAGUCHI, J.KAI & H. YASUDA ----	---- ---- ----	---- ---- ----	Y A DT U	0.5 ----	<0.05 ----	<0.1 ----	<0.1 ---- AT 3σ	----	----	JDY/VOL 6 #1/0204 02/01/8 8 G010A / / JA
07010 50A01 A EBL 16	A	HITACHI LTD., CENTRAL REASEARCH LABORATORY ---- ?, JAPAN ---- DR. NORIO SAITOU ----	HITACHI LTD., NAKA WORKS ---- ?, JAPAN ---- DR. KAZUMITSU NAKAMURA ----	---- ---- ----	N A FP U	0.1 ---- HL-700F	----	----	----	----	1 ---- 4"WAFER	JBK/01-01-88/0 11 01/01/8 8 G012A / / JA

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07010 50A01 A EBL 17	A	JOEL ---- ?, JAPAN ---- MORIYUKI ISOBE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	0.1 ---- SEE MEMO	----	----	----	----	----	JAJ/01-02-90/0 18 01/02/9 0 G013A / / JA
07010 50A01 A EBL 7	A	NTT LABORATORIES ---- ATSUGI-SHI, KANAGAWA, 243-01, JAPAN ---- M.KAKUCHI, H.YOSHIHARA & T.TAMAMURA ----	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI, 305, JAPAN ---- H.MAEZAWA, Y.KAGOSHIMA & M. ANDO ----	---- ---- ----	Y A ST U	0.25 ----	----	----	----	----	----	JDY/VOL 6 #6/0216 7 12/01/8 8 G005A 06/01/8 8 JA
07010 50A01 A EBL 6	B	TOSHIBA CORPORATION, ULSI RESEARCH CENTER ---- 1 KOMUKAI-CHO, SAIWAI-KU, KAWASKI 210, JAPAN ---- K.KOYAMA, O.IKENAGA, T.ABE, R.YOSHIKAWA ---- SEE MEMO	TOSHIBA CORPORATION, ULSI RESEARCH CENTER ---- 1 KOMUKAI-CHO, SAIWAI-KU, KAWASKI 210, JAPAN ---- T.TAKIGAWA ----	TOSHIBA CORPORATION, SEMICONDUCTOR SYSTEM ENGINEERING CENTER ---- 580-1 HORIKAWA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- S. WATANABE ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JDY/VOL 6 # 6/02061 12/01/8 8 G004A 07/21/8 8 JA
07010 50A01 A EBL 15	B	TOSHIBA CORPORATION, ULSI RESEARCH CENTER ---- 1, KOMUKAI TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- K.HATTORI, O.IKENAGA, H.WADA, N.IKEDA ----	TOSHIBA CORPORATION, ULSI RESEARCH CENTER ---- 1, KOMUKAI TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- S. TAMMUSHI, E.NISHIMURA, Y.KATOH ----	TOSHIBA CORPORATION, ULSI RESEARCH CENTER ---- 1, KOMUKAI TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- H.KUSAKABE, R.YOSHIKAWA & T.TAKIGAWA ----	Y A DT U	0.2 ---- SEE MEMO	----	----	----	----	----	JAH/VOL 28 #10/206 5 10/01/8 9 G011A / / JA

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TECHNOLOGY: E-BEAM LITHOGRAPHY

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: E-BEAM RESISTS												
07010 50C01 A EBL 9	A	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- T.YOSHIMURA, F.MURAI, H.SHIRAISHI ----	HITACHI LTD., CENTRAL RESEARCH LABORATORY ---- KOKUBUNJI, TOKYO 185, JAPAN ---- S. OKAZAKI ----	---- ---- ----	Y A DT U	----	.2 ----	---- SEE MEMO	----	----	----	JDY/VOL 6 #6/0224 9 12/01/8 8 G006A / / JA
07010 50C01 A EBL 5	A	JOEL LTD. ---- 3-1-2 MUSAHINO, AKISHIMA, TOKYO, JAPAN 196 ---- H.NAKAZAWA, H. TAKEMURA & M.ISOBE ---- JOEL LTD OF JAPAN TEAMED WITH JOEL LTD OF PEABODY MASSACHUSETTS	---- ---- ----	---- ---- ----	Y A DT U	.0035 ----	.025 ----	PMMA ----	----	----	----	JDY/VOL 6 # 6/02019 12/01/8 8 G003B 06/01/8 8 JA
07010 50C01 A EBL 10	C	NEC CORPORATION, FUNDAMENTAL RESEARCH LABORATORIES ---- 4-1-1, MIYAZAKI, MIYAMAE-KU, KAWASKI 213, JAPAN ---- KATSUMI TANIGAKI ----	---- ---- ----	---- ---- ----	Y A DT U	45 ----	.5 ----	---- SEE MEMO	----	----	----	JDY/VOL 6 #1/091 02/01/8 8 G006A / / JA
07010 50C01 A EBL 8	C	NTT LABORATORIES ---- ATSUGI-SHI, KANAGAWA, 243-01, JAPAN ---- M.KAKUCHI, H.YOSHIHARA & T.TAMAMURA ----	PHOTON FACTORY, NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS ---- TSUKUBA-SHI, IBARAKI, 305, JAPAN ---- H.MAEZAWA, Y.KAGOSHIMA & M. ANDO ----	---- ---- ----	Y A DT U	095 ----	0.25 ----	PMMA ----	----	----	----	JDY/VOL 6 #6/0216 7 12/01/8 8 G005B 06/01/8 8 JA

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TECHNOLOGY: E-BEAM LITHOGRAPHY

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07010 50C01 A EBL 13	B	TOSHIBA CORPORATION, VLSI RESEARCH CENTER ---- 1, KOMUKAI, TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- S.TAMAMUSHI, H.WADA, Y.OGAWA, I.SASAKI ----	TOSHIBA CORPORATION, VLSI RESEARCH CENTER ---- 1, KOMUKAI, TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- M.NAKASUJI, H.KUSAKABE, R.YOSHIKAWA ----	TOSHIBA CORPORATION, VLSI RESEARCH CENTER ---- 1, KOMUKAI, TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- T.TAKIGAWA ----	Y A DT U	20 ----	0.25 ----	PMMA ----	----	----	----	JDY/VOL 6 #1/0212 02/01/8 8 G009B / / JA

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DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: E-BEAM LITHOGRAPHY

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** *************** SUB-TECHNOLOGY: ELECTRON BEAM LITHOGRAPHY (EBL)												
07010 50A01 A G013A EBL 4	A	JOEL LTD. ---- 3-1-2- MUSAHINO, AKISHIMA, TOKYO, JAPAN 196 ---- H.NAKAZAWA, H. TAKEMURA & M.ISOBE ---- TEAMED WITH AMERICAN JOEL LTD TEAM LOCATED IN MASSACHUSETTS	---- ---- ----	---- ---- ----	Y A DT U	.1 ----	.10 ---- 3.5	----	----	----	----	JDY/VOL 6 #6/0201 9 12/01/8 8 G003A 06/01/8 8 JA
07010 50A01 A G004A EBL 12	B	TOSHIBA CORPORATION, VLSI RESEARCH CENTER ---- 1, KOMUKAI, TOSHIBA-CHO, SAIWA-KU, KAWASKI 210, JAPAN ---- S.TAMAMUSHI, H.WADA, Y.OGAWA, :.SASAKI ----	TOSHIBA CORPORATION, VLSI RESEARCH CENTER ---- 1, KOMUKAI, TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- M.NAKASUJI, H.KUSAKABE, R.YOSHIKAWA ----	TOSHIBA CORPORATION, VLSI RESEARCH CENTER ---- 1, KOMUKAI, TOSHIBA-CHO, SAIWAI-KU, KAWASAKI 210, JAPAN ---- T.TAKIGAWA ----	Y A DT U	0.25 ---- SEE MEMO	0.12 ----	----	----	----	----	JDY/VOL 6 #1/0209 02/01/8 8 G009A / / JA
** *************** SUB-TECHNOLOGY: E-BEAM RESISTS												
07010 50C01 A G003B EBL 18	A	JOEL ---- ?, JAPAN ---- MORIYUKI ISOBE ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	0.1 ----	PMMA ----	----	----	----	JAJ/01- 02-90/0 18 01/02/9 0 G013B / / JA

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ELECTRON BEAM LITHOGRAPHY (EBL)

Electron beam lithography is the process of forming circuit patterns by using a focused electron beam, which can be readily scanned and accurately positioned on a substrate to expose radiation-sensitive material, called e-beam resist. Since EBL can utilize pattern data from a CAD system it does not require the costly set of photomasks used by optical lithography. EBL can achieve higher resolution than any optical lithographic technique, and has in some cases been used to fabricate microcircuit structures with features as small as 100 nanometers (nm) (which is equivalent to 0.1 micron or 0.1 um). Under ideal conditions the resolution limit of EBL is about 0.01 um.

Electron beam exposure systems evolved from the development of the scanning electron microscope in which a beam of electrons from a source, such as a hot tungsten filament, is focused into a fine spot (a pixel) on the object via electron lenses. The focused spot is scanned across the object by applying a sawtooth wave-shape to electrostatic deflection plates. The electrons strike the object and cause secondary electrons and backscattered electrons to be emitted.

These systems use an E-beam writing strategy called "vector scan", which is accomplished by the electron beam's digital pattern generator, which controls the E-beam movement through digital-to-analog converters, current amplifiers and deflection coils. When given the coordinates of a rectangle to be exposed, it moves the beam (turned off) to the top left corner of the rectangle and turns on the beam for one exposure element (exel) of about a microsecond. The beam position is then quickly moved one exel distance (0.125 um) to the right and the beam is turned on again for another exel exposure time. This procedure of move, stop, expose is repeated until the top line of the rectangle is exposed. The beam is then moved down one exel and the process repeated toward the left to expose this second line of the rectangle. The process is continued until the entire height of the desired rectangle has been exposed with slightly overlapping horizontal lines. Because of the slight overlap of each exel and the gaussian distribution of electron intensity within each exel, the resulting electron intensity is very uniform over the surface of the exposed rectangle.

Submicron lithography demands that the precision of pattern placement over the full size of the wafer be better than 0.1 micron, which is beyond the capability of vector scan electron optics described above. Laser interferometry, which employs the digital counting of interference fringes produced by monochromatic light reflected between two mirrors, to achieve precise position control.

Deflection of the E-beam on the wafer surface can be controlled to 0.05 micron, within a total range of 1 mm. The stage on which the wafer is mounted can be moved in steps of no less than 1 micron. The laser interferometer measures the position of the wafer (and stage) relative to where the beam exposure is desired and then deflects the beam to the desired point on the wafer substrate.

Registration of successive E-beam exposures is also required. After an exposure, the wafer must be removed from the exposure system, processed through several steps and then returned to receive the next level pattern, which much be registered to the

first pattern within 0.1 micron. These systems produce alignment or bench marks during the initial exposure, which establish the wafer coordinate system and are used to align the reinserted wafer and to correct for wafer distortions that can be caused by the high-temperature processing between exposures.

To write submicron microelectronic patterns over a silicon wafer requires thousands of stage movements, tens of millions of rectangle scans, and billions of individual exels, all of which would not be possible with a process control computer. The sensitivity of the E-beam resist, and the frequency capability of the equipment generally limit the stepping frequency to about 1 MHz. Thus, to expose 20% of the area of a 4 in dia silicon wafer with a circuit pattern of many 0.5 micron features requires a total of 6 x 10^10 exels and at 1 MHz will take 17 hours.

E-beam lithography systems are subject to three major problems:

1. system complexity and cost
2. proximity effects compensation (electron scattering in the resist and substrate)
3. system throughput

Advanced systems use shaped beams to expose many addresses in parallel while exposing one feature, compared to the vector scan system, which exposes one pixel at a time, but employ lower current densities.

11 G008A A variable spot-shaping system using an electrostatic quadrupole triplet has been developed to provide a more flexible patten generation without loss of beam current accompanying a change of dimension of the shaped beam. The quadrupole electron-beam lithography system (QEBS) consists ofa LaB, electron gun, magnetic illuminating lenses, square apertures, an electrostatic quadrupole triplet, and an octapole deflector. The high precision electrostatic quadrupole triplet has been newly developed for this system. The length of the shaped beam can be varied from 0.3 to 30 um for a rectangular beam and from 1 to 200 um for a linear beam by adjusting the excitation voltages ofthe second and the third quadrupoles. The excitation voltages of the quadrupole triplet are controlled by floating digital/analog (D/A) converters with high voltage amplifiers and high-precision dc voltage sources. Preliminary pattern exposures demonstrate that the QEBS is suitable for forming fine line patterns.

3 G001B FUJITSU HAS DEVELOPED AN ELECTRON BEAM PATTERN GENERATION DEVICE THAT CAN PRODUCE RECTILES FOR 16-MEGABIT DRAMS AT THE RATE OF THREE RECTILES PER HOUR WITH POSITIONING ACCURACY OF LESS THAN 0.1um.

14 G010A

We have developed an electron-beam (e-beam) lithography system named "NOWEL" which utilizes very accurate pattern writing method and high-speed data processing. Accordingly NOWEL makes it possible to manufacture reticles for 16-Mbit dynamic random access memories (DRAM's) or more densely integrated very large scale integrated circuits (VLSI's) . The NOWEL system has three key features: (1) Vertical landing deflection system. This consists of three yokes in series and one short-working-distance lens (M = 0.86). The landing

angle at the corner of the 5-mm^2 main field is < 0.0025 rad. Therefore the butting error arising from a 10-u height variation of the substrate is <0.05 u. Deflection aberration is about 0.2u. (2) Double exposure method called "A/B mode." We adopted a variable shaped beam. The first exposure is made by serial writing with constant-size rectangular spots, and the second one is made on the previously exposed area by shining the beam position and reshaping the beam spots. One-half dosage is given in each exposure. By this method the edge roughness of each pattern is improved to be < 0.05 u. (3) Patten data compression. A hierarchical patten data structure was developed. In the memory cell area the data can be divided into only a few pattern data for cell units and their repetition data, i.e., start positions, pitch data, and numbers of cell units in the cell area. According to the repetition data in the main field the main deflector moves the positions of cell units, written by the subdeflector, with the same pattem data. We call this exposure method "main deflection matrix mode." For fine positioning especially in this mode we developed a 20-bit digital-analog convertor (0.005-u least significant bit). These reduction techniques should compress the amount of total patten data to 1/10 for a 16-Mbit DRAM. By using NOWEL we made a test reticle which contained 16-Mbit cell patterns with total accuracy within 0.1u. In this simplest case only one cell unit with the patterns for 128-bit cells and their repetition data were needed.

16 G012A

17 G013A

We have developed an EB system using high-luminance Zr/o/W in the place of LaB cathode, which is now in general use, and have confirmed an about 100 times improvement in beam current density. By this increase in density, it has become possible to improve the writing time of 0.1 um patterns by seven times that in the past. As a result, it has become possible to use the system more efficiently for producing microwave devices, test- manufacturing X-ray masks, and conducting research on quantum effect devices.

PRINCIPAL WRITING PERFORMANCE CHARACTERISTICS

ACCELERATION VOLTAGE	25kv
CATHODE	Zr/O/W
ELECTRON GUN	1x10^-9 TORR
BEAM-SPOT SIZE	EQUIVALENT TO 30nm
CURRENT DENSITY	500 A/cm^2
BEAM DEFLECTION RANGE	1,600 um SQUARE
JUNCTION ACCURACY	0.03 um
SUPERPOSITION ACCURACY	0.03 um
MATERIAL SIZE	WAFER 2-5" MASK 3-5"
AUTOLOADER	12 CASSETTES/BATCH

4 G003A A THERMALLY ASSISTED FIELD EMISSION ELECTRON BEAMEXPOSURE

Electron beam lithography is widely used to fabricate densely packed devices such as high frequencytransistors, since optical lithography is unable to writethe small patterns required for such devices. One major problem with micropattern writing with an electron beam exposure system, however, is slow writting speed; sincethe system has to write an extremely large number of patterns on low-sensitivity resist with a highly focusedbeam, exposure times are quite long. To speed up thewriting process, we

have attached a thermal fieldemission gun to our electron beam exposure system. Thisgun is designed to increase the electron sourcebrightness and probe current density. In order todetermine this new probe current density, we conducted anextensive evaluation on a complete lithography systemwhich uses a thermal field emission gun. We have
measured a current density of ~ 1000 A/cm^2 at an accelerating voltage of 25 kV and conclude that thislithography system can be put to practical use in production areas requiring high throughput and submicron exposures.

7 G005A In conclusion, soft x-ray Fresnel zone plates and son x-ray transmission gratings have been successfully fabricated using finely focused e-beam lithography and Ta-on-SiN x-ray mask fabrication technology. The optical components were evaluated in x-ray microscopy and x-ray holography which employed a brilliant and highly coherent undulator radiation source.

The resolving power of the zone plate x-ray microscope was estimated to be 0.3 um, which is very close to the Rayleigh limit of 0.25 um for the outermost zone width.

Finally, we constructed a divided wavefront interferometer with x-ray transmission gratings, and estimated the dispersion of undulator radiation to be 1/20.

6 G004A

INTEGRATED DATA CONVERSION FOR THE ELECTRON BEAM EXPOSURESYSTEM EX-7

Because pattern data operations for electron beam (EB)lithography requires the knowledge of shape-to-shape correlation with adjacent patterns, the hierarchicalstructure embedded with the input data is usuallyexpanded. Consequently, drastic incre
ase in both the processing time and data amount has resulted. Toovercome this problem a novel data conversion technique has been developed. It can exploit the hierarchicalstructure and repetitiveness originally incorporated into
large-scale integrated designs to emciently generate EB pattern data. The conversion technique wasimplemented on a large-scale computer to make pattern data for the EX-7 EB exposure system. As a result,the highest density levels of 1- an d 4-Mbit directrandom access memories(DRAMS) , scaled down to 0.5um, were converted within 0.5h of central processing unittime, achieving an average data compaction of 1/20.Overlap elimination and tone reversal were performed at a speed of 1 0^8 primitive shapes per hour. The dataamount increased to 40 from 17 Mbytes of uncorrected data, when the proximity effect correction was performed on the shrinked 4-Mbit DRAM pattern using this conversiontechnique.

15 G011A

THE GENERATION OF A TRIANGULAR AND RECTANGULAR SHAPEDULSI PATTERNS WHICH OFTEN INCLUDE MANY OBLIQUE ANGLES.TOULSI PATTERNS WHICH OFTEN INCLUDE MANY OBLIQUE LINES. TOMAKE USE OF THESE SHAPED BEAMS IN ULSI PATTERN FORMATION,A NEW RECATNGULAR AND TR IANGULAR SHAPED BEAM CALIBRATIONMETHOD HAS BEEN DEVELOPED ON THE EB EXPOSURE SYSTEM EX-7.
THE SHAPED BEAM CALIBRATION METHOD IS ESTABLISHED BYANALYZING THE BEAM CURRENT OF SHAPED BEAMS AND THEBACKSCATTERED ELECTRON SIGNAL FROM A FINE GOLD PARTICLE ON THE TARGET. RESULTANT ACCURACIES WERE 0.013um FOR BEAMSIZE OF 1.6um AND 0.025um FOR T HE RELATIVE BEAM POSITIONON THE TARGET. USING THIS METHOD, 0.2um

ULSI PATTERNSINCLUDING OBLIQUE LINES HAVE BEEN ACCURATELY FORMED.

12 G009A The electron optical column is designed for the electron-beam (EB) exposure system EX-7 employing a vector scanned variably shaped beam (VSB) on a continuously moving stage. The column, which utilizes a high current density of 200 A/c^2 and a high voltage of 50 kV, has been designed for a 0.25 um patterning. Generation of triangular shapes in addition to rectangular shapes reduces shot numbers to enhance throughput. An octapole deflector with small deflection distortion, has been developed for beam shaping. The ray tracing method using an analytical expression for the electric and magnetic field was used to design the objective focusing and deflection system, which is composed of a magnetic lens and dual channel electro-static octapole deflectors. Beam edge resolution including the electron-beam interaction effect is about 0.12 um and distortion is < 0.01 um at the final beam convergence semiangle of 8 mrad and field size of 600um square. As a result, a 0.25 um resist pattern has been obtained over 600 um field. Main deflection field stitching error was <+- 0.04 um (3σ) without deflection distortion correction.

2 G0000

E-BEAM RESISTS

Proximity effects compensation, which is electron scattering in the resist and substrate, has been a serious problem in E-beam lithography. One way of correcting for these effects is to calculate the total dose received by each shape and then to adjest the actual exposure dose for each shape so that the resist is given a reasonably uniform dose. While this is done on some E-beam systems, it is not possible to prevent electrons from scattering into regions not intentionally exposed, and thus, the spaces between adjacent shapes receive some unwanted doses.

Multilayer resist schemes can make proximity correction easier. For example, if the primary electrons do not penetrate to the substrate because of the thick planarizing layer, or if this layer absorbs most of the secondary electrons, the imaging layer can be patterned with better fidelity.

The highest resolution E-beam resists are typically positive resists, which undergo a soulbility rate change due to polymer chain scission. The highest available sensitivity of current resists is approximately 15 uC/cm^2 in materials with dry etch resistance similar to PMMA (polymethyl methacrylate). PMMA etches twice as fast as does AZ1350, a positive novolac-based photoresist (Ar sputter rate etch). Clearly a high-sensitivity, high-resolution (<0.5 um) resist witha good dry-etch resistance is desired to improve processing capabilities and throughput.

Silicon-containing resist systems have received attention for E-beam systems. These resists are organosilicon polymers, which contain silicon in either the backbone or pendent groups. When reactively ion etched in an O2 plasma, a thin film of silicon dioxide forms, which prevents further etching. These resists tend to have sensitivities in the 1 to 10 uC/cm^2 range and are most often proposed as the imaging layer in bilayer systems with the pattern transferred into the bottom layer by RIE, but these resists have only been made in research-scale quantities.

A new type of resist chemistry, dubbed "chemical amplification", is also being studied. This type of chemistry would permit very high sensitivities through radiation-induced chemical changes that lead to catalytic reactions. For example, E-beam radiolysis of the sensitizer, an onium salt, in an end-capped poly (phthalaldehyde) resist, generates acid that catalyzes main chain cleavage of the polymer. A new negative E-beam resist has been announced by Rohm and Haas Co. using the chemical amplification technique. Electron beam exposure of one of the components of the resist generates acid. This acid then catalyzes a second component to form several covalent bonds to the novolac resin, effectively crosslinking the polymer. Not only does this resist have good sensitivity (4 uC/cm^2) and the high etch resistance of the standard novolac-based photoresists, but, in addition, the resolution appears to be the equivalent of that of PMMA.

9 G006A The positive electron beam resist NPR is a composite of a novolac resin and a polymeric dissolution inhibitor. In this resist a surface modified layer is produced on the resist when development is interrupted. The dissolution rate of this layer at low dose is very low. A new process called PRISM (process for resist profile improvement with surface modification) utilizing this layeris proposed. By repetitive development interruption, a steep and accurate resist pro@le is obtained with sidewall protection. This paper describes an investigation into the effects of development interruption on NPR. The surface modified layer produced by the interruption is investigated with gas analysis and x-ray photoelectron spectroscopy. It is found that the dissolution inhibitor poly(2-methylpentene-1-sulfone) accumulates at the resist surface. PRISM can be applied to other resists consisting of aqueous alkaline soluble base resins and polymeric dissolution inhibitors. Improvement of the resist pattern profile is observed in positive-type photoresists by PRISM.

18 G013B We have developed an EB system using high-luminance Zr/O/W in the place of LaB_6 cathode, which is now in general use, and have confirmed an about 100 times improvement in beam current density. By this increase in density, it has become possible to improve the writing time of 0.1 um pattens by seven times that in the past. As a result, it has become possible to use the systemmost efficiently for producing microwave devices, test- manufacturing X-ray masks, and conducting research onquantum efffect devices.

5 G003B A THERMALLY ASSISTED FIELD EMISSION ELECTRON BEAMEXPOSURE SYSTEM

Electron beam lithography is widely used to fabricate densely packed devices such as high frequencytransistors, since optical lithography is unable to writethe small patterns required for such devices. One major problem with micropattern writing with an electron beam exposure system, however, is slow writing speed; sincethe system has to write an extremely large number of low-sensitivity resist with a highly focused beam, exposure times are quite long. To speed up the writingprocess, we have attached a thermal field emission gun toour electron beam exposure system. This gun is designedto increase the electron source brightness and probecurrent density. In order to determine this new probecurrent density, we conducted an extensive evaluationon a complete lithography system which uses a thermal field emission gun. We have measured a current density of ~ 1000 A/cm^2 at an accelerating voltage of 25 kVand conclude that this lithography system can be put topractical use in production areas requiring high throughput and submicron exposures.

10 G006A PRECISE COMPARISONS WERE CONDUCTED BETWEENDIAZONAPHTHOQUINONE-4 AND 5-SULFONATE DIRIVATIVES,FOCUSING ON SUBSTITUENT EFFECTS AND ISOMER EFFECTS. IFTHE SOLUBILITY PROBLEM IN COATING SOLEVENTS IS RESOLVED,POSITIVE RESISTS CONSISTING OF DIAZONAPHTHOQUINONE-4SULFONATE DERIVATIVE AND A NOVOLAK RESIN WILL BE USEDMORE EXTENSIVELY IN THE HIGH VACUUM ELECTRON-BEAMLITHOGRAPHY FIELD.

8 G005B In conclusion, soft x-ray Fresnel zone plates and son x-ray transmission gratings have been successfully fabricated using finely focused e-beam lithography and Ta-on-SiN x-ray mask fabrication technology. The optical components were evaluated in x-ray microscopy and x-ray holography which employed a brilliant and highly coherent undulator radiation source.

The resolving power of the zone plate x-ray microscope was estimated to be 0.3 um, which is very close to the Rayleigh limit of 0.25 um for the outermost zone width.

Finally, we constructed a divided wavefront interferometer with x-ray transmission gratings, and estimated the dispersion of undulator radiation to be 1/20.

13 G009B The electron optical column is designed for the electron-beam (EB) exposure system EX-7 employing a vector scanned variably shaped beam (VSB) on a continuously moving stage. The column, which utilizes a high current density of 200 A/c^2 and a high voltage of 50 kV, has been designed for a 0.25 um patterning. Generation of triangular shapes in addition to rectangular shapes reduces shot numbers to enhance throughput. An octapole deflector with small deflection distortion, has been developed for beam shaping. The ray tracing method using an analytical expression for the electric and magnetic field was used to design the objective focusing and deflection system, which is composed of a magnetic lens and dual channel electrostatic octapole deflectors. Beam edge resolution including the electron-beam interaction effect is about 0.12 um and distortion is < 0.01 um at the final beam convergence semiangle of 8 mrad and field size of 600um square. As a result, a 0.25 um resist pattern has been obtained over 600 um field. Main deflection field stitching error was <+- 0.04 um (3o) without deflection distortion correction.

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN

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APPENDIX H

DIAMOND COATINGS AND FILM (DCF)

0704010A00 - DCF - SYSTEM PERFORMANCE

0704010B07 - DCF - PROCESS - WAFER

0704010B08 - DCF - PROCESS - SPOT

0704010B09 - DCF - PROCESS - LARGE SURFACES

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** *** SUB-TECHNOLOGY: DIAMOND COATINGS & FILMS								
07040 10A00	A	BL		B	H0000		Y	
07040 10A00	A	JA	E	P	H190A	P	Y	
07040 10A00	A	JA	E	P	H008A	P	Y	?
07040 10A00	A	JA	A	P	H039A	P	Y	AOYAMA GAKUIN UNIVERSITY, DEPT. OF ELECTRICAL ENG. & ELECTRONICS
07040 10A00	A	JA	E	S	H156A	H191B	Y	CANON
07040 10A00	A	JA	E	S	H189A	H191B	Y	CANON
07040 10A00	A	JA	E	P	H191B	P	Y	CANON RESEARCH CENTER
07040 10A00	A	JA	E	P	H184A	P	Y	IDEMITSU PETROCHEMICAL CO., LTD.
07040 10A00	A	JA	C	P	H001J	P	Y	JAPANESE NATIONAL RESEARCH LABORATORY OF METROLOGY AND SEIKO INSTRUMENTS
07040 10A00	A	JA	E	P	H193A	P	Y	KOBE STEEL
07040 10A00	A	JA	E	S	H134A	193A	Y	KOBE STEEL LTD.
07040 10A00	A	JA	A	P	H034A	P	Y	NATIONAL RESEARCH LABORATORY OF METROLOGY
07040 10A00	A	JA	E	P	H138A	P	Y	NIPPON INSTITUTE OF TECHNOLOGY
07040 10A00	A	JA	E	P	D185A	P	Y	NIPPON OIL & FATS CO. LTD

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07040 10A00	A	JA	E	P	H167A	P	Y	OSAKA UNIVERSITY
07040 10A00	A	JA	C	S	H113A	H034A	Y	SEIKO INSTRUMENT INC.
07040 10A00	A	JA	E	P	H124A	P	Y	SHOWA DENKO
07040 10A00	A	JA	E	P	H127A	P	Y	SONY CORPORATION
07040 10A00	A	JA	E	P	H168A	P	Y	SUMITOMO ELECTRIC
07040 10A00	A	JA	E	P	H187A	P	Y	SUMITOMO ELECTRIC
07040 10A00	A	JA	E	S	H158A	H168A	Y	SUMITOMO ELECTRIC INDUSTRIES
07040 10A00	A	JA	E	P	H189B	P	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD.
07040 10A00	A	JA	E	P	H001B	P	N	SUMITOMO ELECTRIC OF JAPAN
07040 10A00	A	JA	E	P	H001C	P	Y	SUMITOMO ELECTRIC OF JAPAN
07040 10A00	A	JA	E	P	H158B	P	Y	THE NATIONAL INSTITUTE OD RESEARCH ON INORGANIC MATERIALS
07040 10A00	A	JA	E	P	H166A	P	Y	TOKAI UNIVERSITY
07040 10A00	A	JA	E	P	H155A	P	Y	TOKYO UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

** *** SUB-TECHNOLOGY: DCF - PROCESSES - WAFER

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07040 10B07	A	BL		B	H0000		Y	

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07040 10B07	A	JA	A	S	H042A	H039A	Y	AOYAMA GAKIUN UNIVERSITY, DEPT. OF ELECT. ENGINEERING AND ELECTRONICS
07040 10B07	A	JA	A	P	H039B	P	Y	AOYAMA GAKUIN UNIVERSITY, DEPT. OF ENG. & ELECTRONICS
07040 10B07	A	JA	E	P	H022A	P	Y	ASADA RESEARCH LABORATORY, KOBE STEEL, LTD
07040 10B07	A	JA	D	P	H191A	P	Y	CANON RESEARCH CENTER
07040 10B07	A	JA	D	P	H171A	P	Y	CENTRAL INSTITUTE OF CANON
07040 10B07	A	JA	D	P	H020A	P	Y	CENTRAL RESEARCH LABRATORIES MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD
07040 10B07	A	JA	E	P	H001D	P	N	DENKI KOGYO
07040 10B07	A	JA	A	P	H024A	P	Y	DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING, TOYOHASHI UNIVERSITY OF TEC
07040 10B07	A	JA	A	S	H024B	H024A	Y	DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING, TOYOHASHI UNIVERSITY OF TEC
07040 10B07	A	JA	A	P	H005B	P	N	DEPT. OF ELECTRICAL ENGINEERING AND ELECTRONICS, NIPPON INSTITUTE OF TECHNOLOGY
07040 10B07	A	JA	A	P	H011A	P	Y	DEPT. OF ELECTRONICS, FACULTY OF ENGINEERING, TOKAI UNIVERSITY

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07040 10B07	A	JA	C	P	H009A	P	Y	FACULTY OF ENGINEERING, OSAKA UNIVERSITY
07040 10B07	A	JA	A	S	H001G	H123A	N	FUJITSU LABRATORIES
07040 10B07	A	JA	A	P	H123A	P	Y	FUJITSU LABRATORIES LTD
07040 10B07	A	JA	E	P	H001I	H161A	Y	IDEMITSU PETROCHEMICAL
07040 10B07	A	JA	E	P	H161A	P	Y	IDEMITSU PETROCHEMICAL
07040 10B07	A	JA	E	P	H162A	H161A	Y	IDEMITSU PETROCHEMICAL
07040 10B07	A	JA	B	P	H106A	P	Y	ITAMI LABORATORIES OF SUMITOMO ELECTRIC IND., LTD
07040 10B07	A	JA	E	P	H164A	P	Y	JAPAN SYNTHETIC RUBBER COMPANY
07040 10B07	A	JA	C	S	H075A	H089A	Y	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER
07040 10B07	A	JA	C	P	H081A	P	Y	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER
07040 10B07	A	JA	C	P	H089A	P	Y	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER
07040 10B07	A	JA	B	P	H175A	P	N	KOBE STEEL LTD.
07040 10B07	A	JA			H175B		N	KOBE STEEL LTD.
07040 10B07	A	JA	B	P	H182A	P	Y	KOBE STEEL LTD., ELECTRONIC RESEARCH LABORATORY

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07040 10B07	A	JA	C	S	H182B	H182A	Y	KOBE STEEL LTS., ELECTRONICS RESEARCH LABORATORY
07040 10B07	A	JA	B	P	H032A	P	Y	KYOEI PLASTIC COMPANY
07040 10B07	A	JA	B	P	H174A	P	Y	MITSUBISHI PRODUCT DEVELOPMENT LABAORATORY
07040 10B07	A	JA	B	S	H144B	H174A	Y	MITSUBISHI PRODUCT DVELOPMENT LABRATORY
07040 10B07	A	JA	B	P	H001E	P	N	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIAL
07040 10B07	A	JA	B	S	H005A	H001E	Y	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIALS
07040 10B07	A	JA	C	P	H179A	P	Y	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIALS (NIRIM)
07040 10B07	A	JA	C	P	H034B	P	Y	NATIONAL RESEARCH INSTITUTE OF METROLOGY
07040 10B07	A	JA	B	P	H154A	P	Y	NIPPON INSTITUTE OF TECHNOLOGY
07040 10B07	A	JA	C	P	H134B	P	Y	NIPPON INSTITUTE OF TECHNOLOGY
07040 10B07	A	JA	B	P	H035A	P	Y	NIPPON INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL ENGINEERING
07040 10B07	A	JA	B	S	H070A	H035A	Y	NIPPON INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL ENGINEERING AND ELECTRONICS
07040 10B07	A	JA	C	P	H159A	P	Y	NIPPON KOGYO DAIGAKU

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07040 10B07	A	JA	C	S	H163A	H181A	Y	OSAKA UNIVERSITY
07040 10B07	A	JA	C	P	H181A	P	Y	OSAKA UNIVERSITY, DEPT. OF ELECTRICAL ENGINEERING
07040 10B07	A	JA	C	S	H028A	H181A	Y	OSAKA UNIVERSITY, FACULTY OF ENGINEERING
07040 10B07	A	JA	E	P	H076A	P	Y	OSAKA UNIVERSITY, FACULTY OF ENGINEERING
07040 10B07	A	JA	C	S	H098A	H181A	Y	OSAKA UNIVERSITY, FACULTY OF ENGINEERING
07040 10B07	A	JA	D	P	H122A	P	Y	SCIENCE AND TECHNOLOGY AGENCY'S NATIONAL INSTITUTE OF RESEARCH ON INORGANIC MATE
07040 10B07	A	JA	C	S	H113B	H034B	Y	SEIKO INSTRUMENTS INC.
07040 10B07	A	JA	B	P	H124A	P	Y	SHOWA DENKO
07040 10B07	A	JA	D	P	H157A	P	Y	SUMITOMO CHEMICAL COMPANY
07040 10B07	A	JA	B	P	H160B	P	Y	SUMITOMO ELECTRIC
07040 10B07	A	JA	D	P	H001A	P	N	SUMITOMO ELECTRIC OF JAPAN
07040 10B07	A	JA	C	P	H027A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, RESEARCH LABORATORY OF ENGINEERING MATERIAL
07040 10B07	A	JA	B	S	H027B	H027A	Y	TOKYO INSTITUTE OF TECHNOLOGY, RESEARCH LABORATORY OF ENGINEERING MATERIALS

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07040 10B07	A	JA	B	P	H155A	P	Y	TOKYO UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
** *** SUB-TECHNOLOGY: DCF - PROCESS - SPOT								
07040 10B08	A	BL		B	H0000		Y	
07040 10B08	A	JA	B	P	H005C	P	N	ELECTRONICS TECHNOLOGY CENTER, KOBE STEEL, LTD
07040 10B08	A	JA	E	P	H169A	P	Y	HOYA
07040 10B08	A	JA	E	P	H122A	P	Y	KANAGAWA PREFECTURE INDUSTRIAL LABRATORY
07040 10B08	A	JA	C	S	H148A	175D	N	KOBE STEEL LTD.
07040 10B08	A	JA	B	S	H149A	175D	N	KOBE STEEL LTD.
07040 10B08	A	JA	C	S	H150A	175C	Y	KOBE STEEL LTD.
07040 10B08	A	JA	C	S	H151A	175C	Y	KOBE STEEL LTD.
07040 10B08	A	JA	D	P	H175C	P	N	KOBE STEEL LTD.
07040 10B08	A	JA	C	P	H175D	P	N	KOBE STEEL LTD.
07040 10B08	A	JA	C	P	H175E	P	N	KOBE STEEL LTD.
07040 10B08	A	JA	C	P	H175F	P	N	KOBE STEEL LTD.
07040 10B08	A	JA	C	P	H175G	P	N	KOBE STEEL LTD.
07040 10B08	A	JA	B	P	H175H	P	N	KOBE STEEL LTD.

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07040 10B08	A	JA	D	P	H001F	P	N	KYOEI PLASTIC CO.
07040 10B08	A	JA	C	P	H188B	P	Y	KYOTO UNIVERSITY, FACULTY OF ENGINEERING
07040 10B08	A	JA	E	P	H192A	P	Y	NAGOYA UNIVERSITY, SCHOOL OF SCIENCE
07040 10B08	A	JA	B	P	H001H	P	N	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIAL
07040 10B08	A	JA	D	P	H172A	P	Y	NIHON KOGYO DAIGAKU
07040 10B08	A	JA	C	P	H178A	P	Y	NIPPON INSTITUTE OF TECHNOLOGY
07040 10B08	A	JA	C	S	H178B	H178A	Y	NIPPON INSTITUTE OF TECHNOLOGY
07040 10B08	A	JA	B	S	H178C	175A	Y	NIPPON INSTITUTE OF TECHNOLOGY
07040 10B08	A	JA	C	P	H177A	P	Y	OSAKA UNIVERSITY
07040 10B08	A	JA	C	S	H177B	H177A	Y	OSAKA UNIVERSITY
07040 10B08	A	JA	B	P	H144A	P	Y	SHOWA DENKO KK.
07040 10B08	A	JA	B	P	H064A	P	Y	SUMITOMO ELECTRIC IND, LTD., ITAMI LABORATORIES
07040 10B08	A	JA	B	S	H173A	H186A	Y	SUMITOMO ELECTRIC INDUSTRIES LTD
07040 10B08	A	JA	E	S	H176A	H186A	Y	SUMITOMO ELECTRIC INDUSTRIES LTD
07040 10B08	A	JA	E	P	H186A	P	Y	SUMITOMO ELECTRIC INDUSTRIES LTD.

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07040 10B08	A	JA	B	P	H171B	P	Y	SUMITOMO ELECTRIC INDUSTRIES, LTD
07040 10B08	A	JA	B	P	H183A	P	Y	SUMITOMO METAL MINING COMPANY
07040 10B08	A	JA	B	S	H183B	H183A	Y	SUMITOMO METAL MINING COMPANY
07040 10B08	A	JA	D	P	H180A	P	Y	THE UNIVERSITY OF TOKYO, DEPT.OF METALLURGY AND MATERIALS SCIENCE,
07040 10B08	A	JA	D	P	H165A	P	Y	TOKAI UNIVERSITY
07040 10B08	A	JA	C	P	H071A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, FACULTY OF ENGINEERING
07040 10B08	A	JA	A	P	H170A	P	Y	TOKYO INSTITUTE OF TECHNOLOGY, MECHANICAL ENGINEERING DEPARTMENT
** *** SUB-TECHNOLOGY: DCF - PROCESS - LARGE SURFACES								
07040 10B09	A	BL		B	H0000		Y	

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: DIAMOND COATINGS AND FILMS

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: DIAMOND COATINGS & FILMS							
07040 10A00 A DCF	THERMAL CONDUCTIVITY --- WATTS PER CM K --- IMPR. DIR: H	ELECTRON MOBILITY (ue) --- CM^2/VOLT-SEC --- IMPR. DIR: H	HOLE MOBILITY (uh) --- CM^2/VOLT-SEC --- IMPR. DIR: H	DOPING: ELECTRON CONCENTRATION --- CM^-3 --- IMPR. DIR: H	DOPING: HOLE CONCENTRATION --- CM^-3 --- IMPR. DIR: H	LASER THRESHOLD DAMAGE --- GIGAWATTS/CM^2 --- IMPR. DIR: H	SYS PERF
** ******************** SUB-TECHNOLOGY: DCF - PROCESSES - WAFER							
07040 10B07 A DCF	FILM DEPOSITION RATE --- MICRONS/HOUR (MICROMETERS) --- IMPR. DIR: H	DEPOSITED FILM THICKNESS --- MICRONS --- IMPR. DIR: H	MAX DEPOSITION SURFACE AREA --- DIAMETER IN MM --- IMPR. DIR: H	MINIMUM DEPOSITION TEMPERATURE --- DEGREES C --- IMPR. DIR: L	RAMAN SPECTRUM PEAK --- CM^-1 --- IMPR. DIR: E	--- --- IMPR. DIR:	PROC
** ******************** SUB-TECHNOLOGY: DCF - PROCESS - SPOT							
07040 10B08 A DCF	FILM DEPOSITION RATE --- MICRONS/HOUR (MICROMETER) --- IMPR. DIR: H	DEPOSITED FILM THICKNESS --- MICRONS --- IMPR. DIR: H	MAX DEPOSITED SURFACE AREA --- DIAMETER IN MM --- IMPR. DIR: H	MIN DEPOSTION TEMPERATURE --- DEGREES C --- IMPR. DIR: L	RAMAN SPECTRUM PEAK --- CM^-1 --- IMPR. DIR: E	--- --- IMPR. DIR:	PROC
** ******************** SUB-TECHNOLOGY: DCF - PROCESS - LARGE SURFACES							
07040 10B09 A DCF	DEPOSITED FILM THICKNESS --- ANGSTROMS --- IMPR. DIR: H	FILM DEPOSITION RATE --- SQ. METERS/MIN --- IMPR. DIR: H	MINIMUM DEPOSITION TEMPERATURE --- DEG. C --- IMPR. DIR: L	RAMAN SPECTRUM PEAK --- CM^-1 --- IMPR. DIR: E	--- --- IMPR. DIR:	--- --- IMPR. DIR:	PROCES S

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DATABASE ENTRIES
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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: DIAMOND COATINGS & FILMS												
07040 10A00 A DCF 113	E	---- ---- ---- GENERAL INFORMATION - REPORTED BY NIKKEI SANGYO SHIMBUN 06-19-89 P5	---- ---- ----	---- ---- ----	Y P RD U	---- SEE MEMO	----	----	----	----	----	JAJ/12- 06-89/0 09 12/06/8 9 H190A / / JA
07040 10A00 A DCF 10	E	? ---- ? ---- N.FUJIMORI ---- THIS FINDING WAS USED AS A REFERENCE IN THIS CITING	SAME AS ABOVE ---- ---- T. IMAI ----	SAME AS ABOVE ---- ---- A. DOI ----	Y A DT U	----	----	----	----	----	----	JAG/VOL 9 #7/0350 07/07/8 8 H008A / / JA
07040 10A00 A DCF 67	A	AOYAMA GAKUIN UNIVERSITY, DEPT. OF ELECTRICAL ENG. & ELECTRONICS ---- 6-16-1, CHITOSEDAI, SETAGAYA-KU, TOKYO 157, JAPAN ---- ATSUHITO SAWABE & TADAO INUZUKA ----	---- ---- ----	---- ---- ----	Y A DT U	0110 ---- ELECTR ON-ASS ISTED CVD	----	----	----	----	----	JCF/ #137/08 9 01/01/8 6 H039A 05/13/8 5 JA
07040 10A00 A DCF 115	E	CANON RESEARCH CENTER ---- MORINOSATO, ATSUGI-SHI, KANAGAWA 243-01, JAPAN ---- T.TANIGUCHI, K.HIRABAYASHI, K.IKOMA ----	CANON RESEARCH CENTER ---- MORINOSATO, ATSUGI-SHI, KANAGAWA 243-01, JAPAN ---- N.KURIHARA & M.MATSUSHIMA ----	---- ---- ----	Y A DT U	---- SEE MEMO - GENERA L INFORM ATION	----	----	----	----	----	JAH/VOL 28 #10/L18 48 10/01/8 9 H191B / / JA

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07040 10A00 A DCF 106	E	IDEMITSU PETROCHEMICAL CO., LTD. ---- ?, JAPAN ---- ---- ADVERTISEMENT OF DIAMOND SYNTHESIS ACTIVITY	---- ---- ----	---- ---- ----	Y U FP U	---- SEE MEMO	----	----	----	----	----	JAK/VOL 8 #30/027 04/01/8 9 H184A / / JA
07040 10A00 A DCF 22	C	JAPANESE NATIONAL RESEARCH LABORATORY OF METROLOGY AND SEIKO INSTRUMENTS ---- ?, JAPAN ---- AKIRO ONO AND COWORKERS ----	---- ---- ----	---- ---- ----	Y A DT U	010 ---- LOW METHAN E CONCEN TRATIO N 0.1% BY VOLUME OF THE REACTI VE GAS, HAVE THE THERMA L CONDUC TIVITY OF NATURA L DIAMON D	----	----	----	----	----	JAC/05- 15-89/0 38 05/15/8 9 H001J / / JA
07040 10A00 A DCF 117	E	KOBE STEEL ---- 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- SEE MEMO: DIAMOND THIN FILM BY SELECTIVE AREA VAPOR DEPOSITION	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAJ/01- 11-90/0 06 01/11/9 0 H193A / / JA

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07040 10A00 A DCF 64	A	NATIONAL RESEARCH LABORATORY OF METROLOGY ---- TSUKABA, IBARAKI 305, JAPAN ---- AKIRA ONO & TETSUYA BABA ----	SEIKO INSTRUMENTS AND ELECTRONICS LTD. ---- 6-31-1 KAMEIDO, KOTO-KU, TOKYO 136 ---- HIROYUKI FUNAMOTO & AKIRA NISHIKAWA ----	---- ---- ----	Y A DT U	0100 ---- MICROW AVE PLASMA CVD	----	----	----	----	----	JAH/VOL 25 #10/L80 8 10/01/8 6 H034A 06/09/8 6 JA
07040 10A00 A DCF 55	E	NIPPON INSTITUTE OF TECHNOLOGY ---- SAITAMA, JAPAN ---- Y. HIROSE ---- GENERAL APPLICATION INFORMATION	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JBA / / H138A / / JA
07040 10A00 A DCF 107	E	NIPPON OIL & FATS CO. LTD ---- 10-1, YURAKU-CHO 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- PRODUCER OF DIAMONDS IN THIS ENTRY SEE MEMO FOP CONTENT	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JBL/VOL 60 #7/0243 8 07/01/8 9 D185A / / JA
07040 10A00 A DCF 43	E	OSAKA UNIVERSITY ---- OSAKA, JAPAN ---- UNKNOWN ----	OSAKA DIAMOND INDUSTRIAL ---- OSAKA, JAPAN ---- UNKNOWN ----	IDEMITSU PETROCHEMICAL AND TOKAI UNIVERSITY ---- ?, JAPAN ---- UNKNOWN ----	Y A DT U	----	----	----	----	----	----	JAJ/07-11-89/0 46 07/11/8 9 H167A / / JA

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07040 10A00 A DCF 30	E	SHOWA DENKO ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAK/06-88/07 06/01/8 8 H124A / / JA
07040 10A00 A DCF 52	E	SONY CORPORATION ---- TOKYO, JAPAN ---- ---- TWEETER LOUDSPEEKERS	ASAHI DIAMOND INDUSTRIAL COMPANY ---- ?, JAPAN ---- ---- ULTRA HARD TOOLS	SEE MEMO FOR COMPANY PARTICIPANTS ---- JAPAN ---- ---- SEMICONDUCTOR APPLICATIONS OF SYNTHETIC DIAMOND FILMS	Y A FP U	----	----	----	----	----	----	JBC/10-25-88/B 7 10/25/8 8 H127A / / JA
07040 10A00 A DCF 44	E	SUMITOMO ELECTRIC ---- 1-3 SHIMAYA 1-CHROME, KONOHANA-KU, OSAKA 544 JAPAN ---- SEE COMMENTS ---- H. NAKAHATA, H. SHIOMI, T. IMAI, N. FUJIMORI	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	---- B-DOPED FILM-RESISTANCE 10^2 TO 10^4 OHMS NONDOPED-FIMS HIGH LEVEL OF RESISTANCE	----	----	JAJ/07-11-89/0 47 07/11/8 9 H168A / / JA
07040 10A00 A DCF 109	E	SUMITOMO ELECTRIC ---- ---- ---- ARTICLE NOTING FIRMS WHO ARE ACTIVE PARTICIPANTS IN DIAMOND TECHNOLOGY	MITSUBISHI METALS ---- ---- ----	ASAHI DIAMOND ---- ---- ---- OTHER FIRMS: NEC, KYOCERA, KOBE STEEL	Y A FP U	---- SEE MEMO	----	----	----	----	----	JED/10-01089/0 126 10/01/8 9 H187A / / JA

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07040 10A00 A DCF 112	E	SUMITOMO ELECTRIC INDUSTRIES, LTD. ---- 1-3, SHIMAYA 1-CHOME, KONOHANA-KU, OSAKA 554, JAPAN ---- NAOHARU FUJIMORI ---- GENERAL ENTRY	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAJ/12-06-89/0 06 12/06/8 9 H189B / / JA
07040 10A00 A DCF 18	E	SUMITOMO ELECTRIC OF JAPAN ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	N A DT U	020 ---- HIGH-T EMPERA TURE, HIGH-P RESSUR E METHOD SINGLE CRYSTA L	----	----	----	----	----	JAC/05-15-89/0 26 05/15/8 9 H001B 01/01/8 5 JA
07040 10A00 A DCF 19	E	SUMITOMO ELECTRIC OF JAPAN ---- ?, JAPAN ---- UNKNOWN ---- SEE MEMO FIELD	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAC/05-15-89/0 30 05/15/8 9 H001C / / JA
07040 10A00 A DCF 34	E	THE NATIONAL INSTITUTE OD RESEARCH ON INORGANIC MATERIALS ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAJ/05-26-89/0 22 05/26/8 9 H158B 11/29/8 8 JA

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07040 10A00 A DCF 42	E	TOKAI UNIVERSITY ---- ?, JAPAN ---- SEE COMMENTS ---- K. OKANAO, H. NARUKI, I. CHOE, Y. AKIBA, T. KUROSE, M. IiDA	NIPPON INSTITUTE OF TECHNOLOGY ---- ?, JAPAN ---- Y. HIROSE ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAH/07-11-89/0 45 07/11/8 9 H166A / / JA
07040 10A00 A DCF 23	E	TOKYO UNIVERSITY OF AGRICULTURE AND TECHNOLOGY ---- TOKYO, JAPAN ---- GISHO NAMBA ----	---- ---- ----	---- ---- ----	Y A DT U	05.1 ---- METHOD - MODIFIED IONIZATION EVAPORATION METHOD LOW TEMPERATURE(300-400 DEG. C, LOW PRESSURE VICKERS HARDNESS 6500	----	----	----	----	----	JAJ/06-30-89/0 02 06/30/8 9 H155A 12/06/8 8 JA

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** ************** SUB-TECHNOLOGY: DCF - PROCESSES - WAFER												
07040 10B07 A DCF 68	A	AOYAMA GAKUIN UNIVERSITY, DEPT. OF ENG. & ELECTRONICS ---- 6-16-1, CHITOSEDAI, SETAGAYA-KU, TOKYO 157, JAPAN ---- ATSUHITO SAWABE & TADAO INOZUKA ----	---- ---- ----	---- ---- ----	Y A DT U	05 ---- ELECTRON ASSISTED CVD	----	----	0500 ---- 823K	01333 ----	----	JCF/06-01-86/089 06/01/86 H039B 05/13/85 JA
07040 10B07 A DCF 14	E	ASADA RESEARCH LABORATORY, KOBE STEEL, LTD ---- AZA-MARUYAMA, GOMO, NADA-KU, KOBE 657, JAPAN ---- SEE COMMENTS FOR NAMES ---- KOJI KOBASHI, KOZO NISHIURA, YOSHIO KAWATE, AND TAKEFUMI HORIUCHI	---- ---- ----	---- ---- ----	Y A DT U	---- MICROWAVE-GENERATED PLASMA CVD METHOD OF METHANE-HYDROGEN MIXED GAS FILMS SYNTHESIZED FOR 7 HOURS	----	----	----	----	----	JAI/MAY-JUN88/1816 06/01/88 H022A 08/17/87 JA
07040 10B07 A DCF 114	D	CANON RESEARCH CENTER ---- MORINOSATO, ATSUGI-SHI, KANAGAWA, JAPAN 243-01 ---- T.TANIGUCHI, K.HIRABAYASHI, K.IKOMA ----	CANON RESEARCH CENTER ---- MORINOSATO, ATSUGI-SHI, KANAGAWA, JAPAN 243-01 ---- N.IWASAKI KURIHARA & M. MATSUSHIMA ----	---- ---- ----	Y A DT U	---- HOT-FILAMENT CVD METHOD	01 ----	----	0800 ----	----	----	JAH/VOL 28 #10/L1848 10/01/89 H191A / / JA

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07040 10B07 A DCF 74	D	CENTRAL INSTITUTE OF CANON ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	----	002 ---- HOT FILAMENT CVD AND OTHER LAYERS WERE FORMED BY REACTIVE VAPOR DEPOSITION	----	----	----	----	JAJ/07-20-89/03 07/20/89 H171A 04/24/89 JA
07040 10B07 A DCF 13	D	CENTRAL RESEARCH LABRATORIES MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD ---- MORIGUCHI, OSAKA 570, JAPAN ---- MAKOTO KITABATAKE ----	CENTRAL RESEARCH LABRATORIES, MATSUSHITA ELECTRIC INDUSTRIAL CO. LTD ---- MORIGUCHI, OSAKA 570, JAPAN ---- KIYOTAKA WASA ----	---- ---- ----	Y A DT U	0.4 ---- ION ASSISTED DEPOSITION PVD GROWTH OF DIAMOND AT ROOM TEMPERATURE, NON-DIAMOND SUBSTRATE USED, SYNTHESIS ACHIEVED AT LOW TEMPERATURE AND LOW PRESSU	1.5 ----	100 ---- ON A GRAPHITE TARGET DISK	---- ROOM TEMPERATURE	----	----	JAI/VOL 6 #3/1793 06/01/88 H020A 08/24/87 JA

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07040 10B07 A DCF 20	E	DENKI KOGYO ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	N A DT U	----	----	075 ---- BELL JAR REACTO R HIGH QUALIT Y FILMS	----	----	----	JAC/05-15-89/0 36 05/14/8 9 H001D / / JA
07040 10B07 A DCF 15	A	DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING, TOYOHASHI UNIVERSITY OF TEC ---- TENPAKU, TOYOHASHI 440 ---- TETSUYA SATO ----	TOYOTA MOTOR CORPORATION, HIGASHIFUJI TECHNICAL CENTER ---- MISHUKU, SUSONOSHI, SHIZUOKA 410-11 ---- SHIGEO FURUNO, MITSUGU HANABUSA ----	---- ---- ----	Y A DT U	01.2 ---- PULSED -LASER EVAPOR ATION METHOD , FILM QUALIT Y DIAMON D-LIKE	---- FILM WERE THICKE ST AT THE POINT CLOSES T TO THE LASER BEAM	----	50 ----	----	----	JAH/VOL 26 #9/L148 7 09/10/8 7 H024A 07/07/8 7 JA
07040 10B07 A DCF 8	A	DEPT. OF ELECTRICAL ENGINEERING AND ELECTRONICS, NIPPON INSTITUTE OF TECHNOLOGY ---- 4-1 GAKUENDAI, MIYASHIRO, MINAMISAITAMA, SAITAMA, 345 ---- YOICHI HIROSE ---- ACHIEVED APPROXIMATELY 1986	---- ---- ----	---- ---- ----	N A DT U	08 ---- HOT FILAME NT METHOD USING ORGANI C COMPOU NDS THE MARKED INCREA SE IN GROWTH RATE IS ATTRIB UTED TO THE HIGH DENSIT Y OF METHYL	----	----	----	----	----	JAE/VOL 38 #8/4071 08/15/8 8 H005B / / JA

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07040 10B07 A DCF 12	A	DEPT. OF ELECTRONICS, FACULTY OF ENGINEERING, TOKAI UNIVERSITY ---- 1117 KITAKANAME, HIRATSUKA, KANAGAWA, 259-12 ---- K. OKANO, H. NARUKI, Y.AKIBA ----	DEPT. OF ELECTRONICS, FACULTY OF ENGINEERING, TOKAI UNIVERSITY ---- 1117 KITAKANAME, HIRATSUKA, KANAGAWA, 259-12 ---- T. KUROSU, M. IIDA ----	DEPT. OF ELECTRICAL ENGINEERING AND ELECTRONICS, NIPPON INSTITUTE OF TECHNOLOGY ---- 4-1 GAKUENDAI, MIYASHIRO, MINAMISAITAMA, SAITAMA, 345 ---- YOICHI HIROSE ----	Y A DT U	010 ---- THERMAL FILAMENT CVD METHOD, Si(100) SUBSTRATE WITH SURFACES SCRATCHED BY DIAMOND PASTE, REACTANT GAS RATIO AGAINST HYDROGEN WAS 2VOL%, GAS FLOW RATE 50SCCM, GAS PRESSURE 760 TORR., REACTANT TIME 2 HOURS	----	----	0850 ----	----	----	JAH/V27 #2/L173 -L175 02/01/88 H011A 11/14/87 JA

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07040 10B07 A DCF 11	C	FACULTY OF ENGINEERING, OSAKA UNIVERSITY ---- SUITA, OSAKA 565 ---- SEE COMMENTS FOR NAMES ---- HIROSHI KAWARADA, JUN-ICHI SUZUKI, KING-SHENG MAR, YOSHIHIRO YOKOTA, AKIO HIRAKI	OSAKA DIAMOND INDUSTRIAL CO. ---- SAKAI CITY, OSAKA, 593 ---- KAZUHITO NISHIMURA ----	PLANNING AND DEVELOPMENT CENTER, IDEMITSU PETROCHEMICAL LTD ---- KIMITSU, CHIBA 299-02 ---- TOSHIMICHI ITO ----	Y A DT U	---- MAGNETO-MICROWAVE PLASMA CVD AND USUAL MICROWAVE PLASMA CVD, DEPOSITION ON SI 100 SUBSTRATES	03 ----	----	0900 ----	----	----	JAH/VOL 27 #4/L683 04/04/88 H009A 12/01/87 JA
07040 10B07 A DCF 28	A	FUJITSU LABRATORIES LTD ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	0180 ---- PLASMA JETTING METHOD	----	----	----	----	----	JAA/VOL 3 #1/002 02/10/89 H123A 11/24/87 JA
07040 10B07 A DCF 21	E	IDEMITSU PETROCHEMICAL ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	---- DEPOSITED FROM 40% HYDROGEN	----	----	----	---- STILL EXHIBITS A REASONABLE RAMAN SPECTRUM	----	JAC/05-15-89/037 05/15/89 H001I / / JA

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07040 10B07 A DCF 37	E	IDEMITSU PETROCHEMICAL ---- ?, JAPAN ---- T. ITO, A. MASUDA, Y. ETOH ---- 49TH AUTUMN MEETING OF THE JAPAN SOCIETY OF APPLIED PHYSICS	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	0600 ---- MICROW AVE PLASMA CVD	----	----	JAJ/07-11-89/0 40 07/11/8 9 H161A 10/04/8 8 JA
07040 10B07 A DCF 38	E	IDEMITSU PETROCHEMICAL ---- ?, JAPAN ---- T.ITO, A. MASUDA, Y. ETOH ---- THE 49TH AUTUMN METTING OF THE JAPAN SOCIETY OF APPLIED PHYSICS	OSAKA UNIVERSITY ---- OSAKA, JAPAN ---- H.TANAKA S.FUKUTOMI, K. NISHIMOTO ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAJ/07-11-89/0 41 07/11/8 9 H162A 10/04/8 8 JA
07040 10B07 A DCF 99	B	ITAMI LABORATORIES OF SUMITOMO ELECTRIC IND., LTD ---- 1-1, 1-CHOME, KOYAKITA, ITAMI 664, JAPAN ---- N. FUJIMORI, A. IKEGAYA, T. IMAI ----	ITAMI LABORATORIES OF SUMITOMO ELECTRIC IND., LTD ---- 1-1, 1-CHOME, KOYAKITA, ITAMI 664, JAPAN ---- K. FUKUSIMA & N. OHTA ----	---- ---- ----	Y A DT U	08 ---- HOT-FI LAMENT AND DC PLASMA CO-ENH ANCED CVD	----	----	0900 ----	1332 ----	----	JBS/04-24-98/0 164 04/24/8 9 H106A / / JA
07040 10B07 A DCF 40	E	JAPAN SYNTHETIC RUBBER COMPANY ---- ?, JAPAN ---- SEE COMMENTS ---- J. WEI, H. KAWARADA, J. SUZUKI, K.S. MAR, Y. YOKOTA, A. HIRAKI	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAJ/07-11-89/0 43 07/11/8 9 H164A / / JA

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07040 10B07 A DCF 96	C	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER ---- KOBE 651, JAPAN ---- K. KOBASHI ---- THIS STUDY INVOLVED RESERCERS FROM NORTH CAROLINA STATE UNIVERSITY	---- ---- ----	---- ---- ----	Y A DT U	---- MICROW AVE PLASMA CVD	----	----	0800 ----	----	----	JBS/ABS . 88/0130 04/24/8 9 H081A / / JA
07040 10B07 A DCF 97	C	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER ---- 1-5-5 TAKATSUKADAI, NISHI-KU, KOBE 67302, JAPAN ---- K.KOBASHI, K.NISHIMURA, K.MIYATA ----	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER ---- 1-5-5 TAKATSUAKADAI, NISHI-KU, KOBE 673-02,JAPAN ---- K.KUMAGAI & Y.KAWATE ----	---- ---- ----	Y A DT U	---- MICROW AVE PLASMA CVD	01 ---- 7 HOURS	----	0800 ----	----	----	JBS/ABS . 97/0142 04/24/8 9 H089A / / JA
07040 10B07 A DCF 79	B	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	08 ---- HOT FILAME NT CVD	----	010 ----	----	----	----	JBG/06-09-88/0 1 06/09/8 8 H175A 06/09/8 8 JA
07040 10B07 A DCF 102	B	KOBE STEEL LTD., ELECTRONIC RESEARCH LABORATORY ---- TEKKO BLDG., 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- H.HAYASHI, Y.OHNISHI, K.KOBASHI ----	KOBE STEEL LTD., ELECTRONICS RESEARCH LABORATORY ---- TEKKO BLDG., 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- K. NISHIMURA, K. MIYATA ----	KOBE STEEL LTD., SUPERCONDUCTING & CYROGENIC TECHNOLOGY CENTER ---- TEKKO BLDG., 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- Y.KAWATE ----	Y A DT U	0.8 ---- RF PLASMA , DIAMON D-LIKE CARBON S	----	070 ----	0200 ----	1332 ---- DCL FILMS CONTAI N TRACES OF DIAMON D STRUCT URE	----	JDB/REV IEW #6/014 08/01/8 9 H182A / / JA

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07040 10B07 A DCF 63	B	KYOEI PLASTIC COMPANY ---- 3-17, SAKURAGI, CHICHIBU-SHI, SAITAMA 368, JAPAN ---- KAZUHIRO SUZUKI ----	AOYAMA GAKUIN UNIVERSITY ---- 6-16-1, CHITOSEDAI, SETAGAYA-KU, TOKYO 157, JAPAN ---- A. SAWABE, H.YASUDA, T. INUZUKA ----	---- ---- ----	Y A DT U	020 ---- DC PLASMA CHEMICAL VAPOR DEPOSITION	020 ----	----	0800 ----	----	----	JCE/LETTER 50/0728 03/23/87 H032A 10/03/86 JA
07040 10B07 A DCF 78	B	MITSUBISHI PRODUCT DEVELOPMENT LABAOFATORY ---- HYOGO, JAPAN ---- Y. GOTO ----	---- ---- ----	---- ---- ----	Y A DT U	06 ---- LASER-INDUCED CVD	----	----	0800 ----	1333 ----	----	JBB/02-09-89/046 02/09/89 H174A / / JA
07040 10B07 A DCF 3	B	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIAL ---- TSUKUBA, JAPAN ---- SEEICHIRO MATSUMOTO ---- HEATED FILAMENTED PROCESS	---- ---- ----	---- ---- ----	N A DT U	020 ---- HEAT-FILAMENT PROCESS LOW PRESSURE	----	0200 ----	----	----	----	JAC/05-15-89/034 05/15/89 H001E / / JA
07040 10B07 A DCF 93	C	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIALS (NIRIM) ---- TSUKUBA, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	00.20 ----	----	0100 ----	----	----	----	JAK/VOL8 #30/065 04/01/89 H179A 11/01/88 JA

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07040 10B07 A DCF 65	C	NATIONAL RESEARCH INSTITUTE OF METROLOGY ---- TSUKUBA, IBARAKI 305, JAPAN ---- AKIRA ONO & TETSUYA BABA ----	SEIKO INSTRUMENTS AND ELECTRONICS LTD ---- 6-31-1 KAMEIDO, KOTO-KU, TOKYO 136 ---- HIROYUKI FUNAMOTO & AKIRA NISHIKAWA ----	---- ---- ----	Y A DT U	---- MICROWAVE PLASMA CVD	030 ----	----	----	01333 ----	----	JAH/VOL 25 #10/L808 10/01/86 H034B 06/09/86 JA
07040 10B07 A DCF 25	B	NIPPON INSTITUTE OF TECHNOLOGY ---- ?, JAPAN ---- YOICHI HIROSE ----	---- ---- ----	---- ---- ----	Y A DT U	250 ---- ARC ELECTRICAL DISCHARGE PLASMA CVD HIGH PRESSURE HIGH TEMPERATURE FILM QUALITY GOOD 4 TO 5 TIMES THE SPEED OF OTHER FILM GROWTH METHODS	----	----	5000 ----	----	----	JAJ/06-30-89/001 06/30/89 H154A 11/24/88 JA

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07040 10B07 A DCF 54	C	NIPPON INSTITUTE OF TECHNOLOGY ---- 4-1 GAKUENDAI, MIYASHIRO MACHI, SAITAMA, JAPAN ---- M. MURAKAWA ----	---- ---- ----	---- ---- ----	Y A DT U	010 ---- ETHANOL CVD	010 ----	----	----	----	----	JBF/VOL 18 #14/02 04/12/89 H134B / / JA
07040 10B07 A DCF 66	B	NIPPON INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL ENGINEERING ---- MIYASHIRO, MINAMISAITAMA, SAITAMA 345, JAPAN ---- YOICHI HIROSE & YUKI TERASWA ----	---- ---- ----	---- ---- ----	Y A DT U	010 ---- THERMAL CVD	033 ---- AFTER 4 HOURS	----	0500 ----	01333 ----	----	JAH/VOL 25 #6/L519 06/01/86 H035A 05/12/86 JA
07040 10B07 A DCF 35	C	NIPPON KOGYO DAIGAKU ---- ?, JAPAN ---- SEE COMMENTS ---- YOICHI HIROSE, MAKOTO MITSUIZUMI, NOBUYUKI FUJITA, SADAO TAKEUCHI	---- ---- ----	---- ---- ----	Y A DT U	---- COMBUSTION FLAME METHOD ATMOSPHERIC PRESSURE	----	----	0600 ----	---- RAMAN SPECTRSCOPIC ANALYS IS USED	----	JAJ/07-11-89/034 07/11/89 H159A 09/25/88 JA
07040 10B07 A DCF 58	C	OSAKA UNIVERSITY, DEPT. OF ELECTRICAL ENGINEERING ---- SUITA, OSAKA 565, JAPAN ---- SEE COMMENTS FOR NAMES ---- *J. SUZUKI, H. KAWARADA, K.S. MAR, J. WEI, Y. YOKOTA, A. HIRAKI	---- ---- ---- * ABOVE NAME IS ON LEAVE FROM SHIMADZU CO.	---- ---- ----	Y A DT U	---- MAGNO-MICROWAVE PLASMA CVD-LOW PRESSURE, LOW TEMPERATURE	----	0160 ----	0600 ----	1333 ----	----	JAH/VOL 28 #2/L281 02/02/89 H181A / / JA

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07040 10B07 A DCF 95	E	OSAKA UNIVERSITY, FACULTY OF ENGINEERING ---- SUITA-SHI, OSAKA 565, JAPAN ---- JING SHENG MA, HIROSHI KAWARADA ----	OSAKA UNIVERSITY, FACULTY OF ENGINEERING ---- SUITA-SHI, OSAKA 565, JAPAN ---- J.I.SAZUKI, J. WEI, Y.YOKOTA, A.HIRAKI ----	CANON INC, RESEARCH CENTER ---- ATSUKI CITY, KANAGAWA 243-01, JAPAN ---- TAKAO YONEHARA ----	Y A DT U	---- SEE MEMO PLASMA -ASSIS TED CVD	----	----	----	----	----	JBS/ABS . 83/0124 04/24/8 9 H076A / / JA
07040 10B07 A DCF 27	D	SCIENCE AND TECHNOLOGY AGENCY'S NATIONAL INSTITUTE OF RESEARCH ON INORGANIC MATE ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	---- MICROW AVE CVD METHOD	04 ----	0101.6 ---- UNIFOR M COMPOS ITIN	----	----	----	JAA/VOL 4 #3/012 03/13/8 9 H122A / / JA
07040 10B07 A DCF 29	B	SHOWA DENKO ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	---- LOW TEMPER ATURE, LOW PRESSU RE VAPOR PHASE MTHOD	0100 ----	----	----	---- 100% DIAMON D FILM, VICKER S HARDNE SS GREATE R THAN 10^4	----	JAK/06-88/07 06/01/8 8 H124A / / JA
07040 10B07 A DCF 32	D	SUMITOMO CHEMICAL COMPANY ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	----	003 ---- MICROW AVE PLASMA CVD BORON DOPED FILM	----	----	----	----	JAJ/05-26-89/0 24 05/26/8 9 H157A 11/15/8 8 JA

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07040 10B07 A DCF 36	B	SUMITOMO ELECTRIC ---- 1-3,SHIMAYA 1-CHROME, KONOHANA-KU, OSAKA 544 ---- SEE COMMENTS ---- K. TANASE, Y. NISHIBAYASHI, T. IMAI, A. IKEEGAYA, N. FUJIMORI	---- ---- ----	---- ---- ----	Y A DT U	03 ---- MIVCRO WAVE PLASMA CVD	----	---- SURFAC E SCRATC HED BY DIAMON D POWDER AND PROCES SED	0900 ----	1333 ----	----	JAJ/07-11-89/0 39 07/11/8 9 H160B 10/04/8 8 JA
07040 10B07 A DCF 17	D	SUMITOMO ELECTRIC OF JAPAN ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	N A DT U	---- HIGH-P RESSUR E, HIGH TEMPER ATURE TECHNO LGY, PRODUC ED CRYSTA LS OF UP TO TWO CARATS	----	08 ----	----	----	----	JAC/05-15-89/0 25 05/15/8 9 H001A 01/01/8 5 JA
07040 10B07 A DCF 60	C	TOKYO INSTITUTE OF TECHNOLOGY, RESEARCH LABORATORY OF ENGINEERING MATERIAL ---- 4259 NAGATSUTA, MIDORI, YOKOHAMA 227, JAPAN ---- TAKASHI KAWATO & KEN-ICHI KONDO ----	---- ---- ----	---- ---- ----	Y A DT U	01.75 ---- CVD METHOD WITH CH4 FLOW RATE 2.0(SC CM) & OXYEN ADDITI VE	----	----	0850 ----	----	----	JAH/VOL 29 #9/1429 09/01/8 7 H027A 04/09/8 7 JA

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07040 10B07 A DCF 24	B	TOKYO UNIVERSITY OF AGRICULTURE AND TECHNOLOGY ---- TOKYO, JAPAN ---- GISHO NAMBA ----	---- ---- ----	---- ---- ----	Y A DT U	---- MODIFIED IONIZATION EVAPORATION METHOD	----	----	0300 ---- LOW PRESSURE, LOW TEMPERATURE	---- VICKERS HARDNESS OF 6500	----	JAJ/06-30-89/002 06/30/89 H155A 12/06/88 JA
** *************** SUB-TECHNOLOGY: DCF - PROCESS - SPOT												
07040 10B08 A DCF 9	B	ELECTRONICS TECHNOLOGY CENTER, KOBE STEEL, LTD ---- 1-5-5 TAKATSUKADAI, NISHI-KU, KOBE 673-02, JAPAN ---- KOJI KOBASHI ----	ELECTRONICS TECHNOLOGY CENTER, KOBE STEEL, LTD ---- 1-5-5 TAKATSUKADAI, NISHI-KU, KOBE 673-02, JAPAN ---- KOZO NISHIMURA ----	ELECTRONICS TECHNOLOGY CENTER, KOBE STEEL, LTD ---- 1-5-5 TAKATSUKADAI, NISHI-KU, KOBE 673-02, JAPAN ---- YOSHIO KAWATE & TAKEFUMI HORIUCHI ----	N A DT U	0.28 ---- MICROWAVE PLASMA CHEMICAL-VAPOR DEPOSITION, CH4=1%	01.9 ----	----	800 ----	1334 ----	----	JAE/VOL 38 #4/4072 08/15/88 H005C 01/15/88 JA
07040 10B08 A DCF 45	E	HOYA ---- ?, JAPAN ---- Y.SATO, CH.HATA, M.KAMO ----	---- ---- ----	---- ---- ----	Y A DT U	---- MICROWAVE PLASMA CVD, METHANE 3-5%	----	----	----	---- VERIFIED THROUGH SEM OBSERVATION	----	JAJ/07-11-89/048 07/11/89 H169A / / JA
07040 10B08 A DCF 28	E	KANAGAWA PREFECTURE INDUSTRIAL LABRATORY ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	? ---- ELECTRON ASSISTED CHEMICAL VAPOR DEPOSITION	----	----	---- ONE INCH SILICON SUBSTRATE	---- CLAIMS OF ACHIEVING THE CLOSEST TO DATE A CRYSTALLINE STRUCTURE CLOSE TO DIAMOND	----	JAA/VOL 4 #3/012 03/13/89 H122A / / JA

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07040 10B06 A DCF 81	D	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	00.50 ---- MICROW AVE PLASMA CVD	----	050 ----	----	----	----	JBG/06-07-88/0 1 06/07/8 8 H175C 06/07/8 8 JA
07040 10B06 A DCF 82	C	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	020 ---- ELECTR ON-ASS ISTED CVD	----	010 ----	----	----	----	JBG/06-07-88/0 1 06/07/8 8 H175D 06/07/8 8 JA
07040 10B06 A DCF 83	C	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	020 ---- DC PLASMA CVD	----	010 ----	----	----	----	JBG/06-07-88/0 1 06/07/8 8 H175E 06/07/8 8 JA
07040 10B06 A DCF 84	C	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	060 ---- THERMA L PLASMA CVD	----	010 ----	----	----	----	JBG/06-07-88/0 1 06/07/8 8 H175F 06/07/8 8 JA
07040 10B06 A DCF 85	C	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	0180 ---- PLASMA TOURCH CVD	----	05 ----	----	----	----	JBG/06-07-88/0 1 06/07/8 8 H175G 06/07/8 8 JA

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07040 10B08 A DCF 86	B	KOBE STEEL LTD. ---- CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	0400 ---- ARC DISCHA RGE CVD	----	05 ----	----	----	----	JBG/06- 07-88/0 1 06/07/8 8 H175H 06/07/8 8 JA
07040 10B08 A DCF 4	D	KYOEI PLASTIC CO. ---- ?, JAPAN ---- KAZUHIRO SUZUKI ---- ASSISTED BY COLLEAGUES AT AOYAMA GAKUIN UNIVERSITY	---- ---- ----	---- ---- ----	N A DT U	020 ---- DIRECT -CURRE NT PLASMA JET PROCES S	----	010 ----	----	----	----	JAC/05- 15-89/0 34 05/15/8 9 H001F / / JA
07040 10B08 A DCF 110	C	KYOTO UNIVERSITY, FACULTY OF ENGINEERING ---- KYOTO, JAPAN ---- YOCHI TOMII & MUTSUHIKO YOSHIOKA ---- M. YOSHIAKA IS A GRADUATE STUDENT AT THIS UNIVERSITY	NIPPON ALUMINUM MANUFACTURING ---- ?, JAPAN ---- ---- PROJECT DONE IN COLLABORATION WITH ENTRY ABOVE	---- ---- ----	Y A DT U	090-10 0 ---- DC ARC PLASMA METHOD	0900 ----	----	0800 - .1200 ----	----	----	JAJ/12- 06-89/0 07 12/06/8 9 H188B 06/19/8 9 JA
07040 10B08 A DCF 116	E	NAGOYA UNIVERSITY, SCHOOL OF SCIENCE ---- NAGOYA 464-01, JAPAN ---- N.WADA, M.TANI, T.GOTO, T.SATO & M.KATO ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAJ/01- 03-90/0 44 01/03/9 0 H192A / / JA

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07040 10B08 A DCF 6	B	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIAL ---- TSUKABA, JAPAN ---- SEEICHIRO MATSUMOTO ----	---- ---- ----	---- ---- ----	N A DT U	0500 ---- THERMAL PLASMA JET METHOD CONTAMINATION FROM PLASMA NOZZLE CAN DETERIORATE QUALITY OF THE FILM	----	----	----	----	----	JAC/05-15-89/035 05/15/89 H001H / / JA
07040 10B08 A DCF 76	D	NIHON KOGYO DAIGAKU ---- ?, JAPAN ---- F.ALKATSUKA, Y. HIROSE ---- REPORTED IN "JOURNAL OF THE JAPANESE ASSOCIATION OF CRYSTAL GROWTH" DTD 10 JUL 88	---- ---- ----	---- ---- ----	Y A DT U	250 ---- ARC-DISCHARGE CVD METHOD	----	----	5000 ----	1333 ----	----	JAJ/07-11-89/034 07/11/89 H172A / / JA
07040 10B08 A DCF 90	C	NIPPON INSTITUTE OF TECHNOLOGY ---- SAITAMA, JAPAN ---- PROF. YOICHI HIROSE ----	---- ---- ----	---- ---- ----	Y A DT U	0100 ---- OPEN ATMOSPHERIC COMBUSTION FLAME METHOD DIAMOND FILMS	----	----	0600 ----	----	----	JAK/VOL 7 #27/048 09/01/88 H178A / / JA

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07040 10B08 A DCF 88	C	OSAKA UNIVERSITY ---- OSAKA, JAPAN ---- PROF. AKIO HIRAKI ----	---- ---- ----	---- ---- ----	Y A DT U	---- LOW PRESSURE TECHNIQUE	010 ----	030 ----	0700 ----	----	----	JAK/VOL 6 #23/05 08/01/87 H177A / / JA
07040 10B08 A DCF 50	B	SHOWA DENKO KK. ---- 2-10-12, SHIBA-DAIMON, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	---- CVD METHOD	0100 ----	----	----	----	----	JBA/02-06-88/ 02/06/88 H144A 02/06/88 JA
07040 10B08 A DCF 59	B	SUMITOMO ELECTRIC IND, LTD., ITAMI LABORATORIES ---- 1-1, 2-CHOME, KOYAKITA, ITAMI 664, JAPAN ---- AKIO HARA & NAOJI FUJIMORI ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	----	0100 ---- SEE MEMO	----	----	----	----	JBS/?/108 / / H064A / / JA
07040 10B08 A DCF 108	E	SUMITOMO ELECTRIC INDUSTRIES LTD. ---- 1-3, SHIMAYA 1-CHOME, KONOHANA-KU, OSAKA 554, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- SEE MEMO	----	----	---- FIXED PRESSURES AND TEMPERATURES	----	----	JAJ/10-27-89/005 10/27/89 H186A 08/01/89 JA
07040 10B08 A DCF 75	B	SUMITOMO ELECTRIC INDUSTRIES, LTD ---- 1-3, SHIMAYA 1-CHROME, KONOHANA-KU, OSAKA, 554, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	----	00.5 ---- PLASMA CVD METHOD, B-DOPED	----	----	----	----	JAJ/07-20-89/03 07/20/89 H171B 04/24/89 JA

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07040 10B08 A DCF 104	B	SUMITOMO METAL MINING COMPANY ---- 1-3, OHTEMACHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- S.FUTAKI, K. SHIRAISHI, S. MATSUMOTO ---- EXCERTS FROM AN ARTICLE BY AUTHORS	---- ---- ----	---- ---- ----	Y A DT U	---- DIRECT CURREN T ARC DISCHA RGES, DISCHA RGES SMALL COMPAR ED TO HF METHOD	---- FILM THICKN ESS AND FORMAT ION NOT UNIFOR M	030 ---- DEPEND ANT ON REACTI ON CONDIT IONS	---- MEASUR EMENTS NOT RELIAB LE BECAUS E OF THE STRONG LIGHT REFLEC TED FROM THE PLASMA	----	----	JAJ/09-29-89/0 01 09/29/8 9 H183A / / JA
07040 10B08 A DCF 57	D	THE UNIVERSITY OF TOKYO, DEPT.OF METALLURGY AND MATERIALS SCIENCE, ---- HONGO 7-3-1, BUNKYO-KU, TOKYO 113, JAPAN ---- Y. MITSUDA, T.YOSHIDA, K.AKASHI ----	---- ---- ----	---- ---- ----	Y A DT U	030 ---- MICROW AVE PLASMA TOURCH METHOD AT ATMOSP HERIC PRESSU RE	----	025 ----	01200 ----	1333 ----	----	JBL/VOL 60 #2/0249 02/01/8 9 H180A / / JA
07040 10B08 A DCF 41	D	TOKAI UNIVERSITY ---- ?, JAPAN ---- SEE COMMENTS ---- H. NARUKI, K.OKANO, I. CHOE, Y. AKIBA, T. KUROSE, M. IIDA	NIPPON INSTITUTE OF TECHNOLOGY ---- ?, JAPAN ---- Y. HIROSE ---- INFORMATION OBTAINED FROM THE 49TH AUTUMN MEETING OF THE JAPAN SOCIETY OF APPLIED PHYSICS	---- ---- ----	Y A DT U	010 ---- GROWTH RATE SIMILA R TO NON-DO PED FILM	---- FLAT	---- SPOT SHAPED	----	----	----	JAJ/07-11-89/0 44 07/11/8 9 H165A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07040 10B08 A DCF 71	C	TOKYO INSTITUTE OF TECHNOLOGY, FACULTY OF ENGINEERING ---- 1-12-1, O-OKAYAMA, MEGURO-KU, TOKYO 152, JAPAN ---- N. OHTAKE, H. TOKURA, Y. KURIYAMA ----	TOKYO INSTITUTE OF TECHNOLOGY, FACULTY OF ENGINEERING ---- 1-12-1, O-OKAYAMA, MEGURO-KU, TOKYO 152, JAPAN ---- Y. MASHIMO & M. YOSHIKAWA ----	---- ---- ----	Y A DT U	---- ARC DISCHA RGE PLASMA CVD	----	050.8 ----	0500 ----	----	----	JBS/ABS . 78/0116 04/24/8 9 H071A / / JA
07040 10B08 A DCF 73	A	TOKYO INSTITUTE OF TECHNOLOGY, MECHANICAL ENGINEERING DEPARTMENT ---- TOKYO, JAPAN ---- MASANORI YOSHIKAWA, PROFESSOR ----	ONODA CEMENT COMPANY LTD ---- ?, JAPAN ---- KAZUHO IMAMURA ---- PRESIDENT	---- ---- ----	Y A DT U	0900 ---- ARC-DI SCHARG E PLASMA METHOD	----	----	0700 ----	----	----	JAJ/07- 20-89/0 04 07/20/8 9 H170A 04/04/8 9 JA

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** *************** SUB-TECHNOLOGY: DIAMOND COATINGS & FILMS												
07040 10A00 A H191B DCF 31	E	CANON ---- ?, JAPAN ---- UNKNOWN ----	---- ---- ----	---- ---- ----	Y A DT U	---- CVD METHOD	----	----	----	----	----	JAJ/07- 06-89/0 1 07/06/8 9 H156A 05/08/8 9 JA
07040 10A00 A H191B DCF 114	E	CANON ---- ?, JAPAN ---- ---- GENERAL INFORMATION ARTICLE	---- ---- ----	---- ---- ----	Y A DT U	---- SEE MEMO	----	----	----	----	----	JAJ/12- 06-89/0 08 12/06/8 9 H189A / / JA
07040 10A00 A 193A DCF 53	E	KOBE STEEL LTD. ---- 1-3-18, WAKINOHAMACHO, CHUO-KU, KOBE 651, JAPAN ---- ---- APPLICATION INFORMATION	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JBF/VOL 18 #14/01 04/12/8 9 H134A 04/05/8 9 JA
07040 10A00 A H034A DCF 102	C	SEIKO INSTRUMENT INC. ---- 563, TAKATSUKA-SHINDEN, MATSUDO-SHI, CHIBA 271, JAPAN ---- A. NISHIKAWA & H. FUNAMOTO ---- SEE MEMO	NATIONAL RESEARCH LABORATORY OF METROLOGY ---- TSUKUBA, IBARAKI 305, JAPAN ---- A. ONO & T. BABA ----	---- ---- ----	Y A DT U	010 ---- MICROW AVE PLASMA CVD THERMA L CONDUC TIVITY OBTAIN ED = 1000 Wm^-1 K^-1	----	----	----	----	----	JBS/04- 24-89/0 171 04/24/8 9 H113A / / JA

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07040 10A00 A H168A DCF 33	E	SUMITOMO ELECTRIC INDUSTRIES ---- 1-3 SHIMAYA L-CHOME, KONOHANA-KU, OSAKA, 544 JAPAN ---- NAOJI FUJIMORI ----	---- ---- ----	---- ---- ----	Y A DT U	----	----	----	----	----	----	JAJ/05- 26-89/0 22 05/26/8 9 H158A 12/02/8 8 JA
** ############### SUB-TECHNOLOGY: DCF - PROCESSES - WAFER												
07040 10B07 A H039A DCF 69	A	AOYAMA GAKIUN UNIVERSITY, DEPT. OF ELECT. ENGINEERING AND ELECTRONICS ---- 1-16-1 CHITOSEDAI, SETAGAYA-KU, TOKYO 157, JAPAN ---- ATSUHITO SAWABE & TADAO INUZUKA ----	---- ---- ----	---- ---- ----	Y A DT U	05 ---- ELECTR ON-ASS ISTED CVD	012 ----	----	0850 ----	----	----	JCE/ VOL 46 #2/0146 01/15/8 5 H042A / / JA
07040 10B07 A H024A DCF 16	A	DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING, TOYOHASHI UNIVERSITY OF TEC ---- TENPAKU, TOYOHASHI 440 ---- TETUYA SATO ----	TOYOTA MOTOR CORPORATION, HIGASHIFUJI TECHNICAL CENTER ---- MISHUKU, SUSONOSHI, SHIZUOKA 410-11 ---- SHIGEO FURUNO, MITSUGU HANABUSA ----	---- ---- ----	Y A DT U	05 ---- PULSED LASER EVAPOR ATION, FILM QUALIT Y POOR METHOD	---- FILMS WERE THICKE ST AT THE POINT CLOSES T TO THE LASER BEAM	----	---- ROOM TEMPER ATURE	----	----	JAH/VOL 26 #9/L148 7 09/01/8 7 H024B 07/07/8 7 JA
07040 10B07 A H123A DCF 5	A	FUJITSU LABRATORIES ---- ATSUGI, JAPAN ---- NAGAAKI KOSHINO ----	FUJITSU LABRATORIES ---- ATSUGI, JAPAN ---- KAZUAKI KURIHARA ----	---- ---- ----	N A DT U	0500 ---- THERMA L PLASMA JET METHOD CONTAM INATIO N FROM PLASMA NOZZLE CAN DETERI	----	----	----	----	----	JAC/05- 15-89/0 35 05/15/8 9 H001G / / JA

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07040 10B07 A H089A DCF 96	C	KOBE STEEL LTD, ELECTRONICS TECHNOLOGY CENTER ---- 1-5-5, TAKATSUKADAI, NISHI-KU, KOBE, 673-02, JAPAN ---- K.KOBASHI, K.MIYATA, K.KUMAGI, A.NAKAUE ----	KOBR STEEL LTD, ELECTRONICS TECHNOLOGY CENTER ---- 1-5-5 TAKATSUKADAI, NISHI-KU, 673-02, JAPAN ---- H.TACHIBANA, T.INOUE, & Y.KAWATE ----	---- ---- ----	Y A DT U	---- ELECTR ON-ASS ISTED CHEMIV AL VAPOR DEPOSI TION	----	----	0750 ----	----	----	JBS/ABS . 82/0122 04/24/8 9 H075A / / JA
07040 10B07 A H182A DCF 105	C	KOBE STEEL LTS., ELECTRONICS RESEARCH LABORATORY ---- TEKKO BLDG., 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- H.HAYASHI, Y.OHNISHI, K. KOBASHI ----	KOBE STEEL LTD., ELECTRONICS RESEARCH LAVBORATORY ---- TEKKO BLDG., 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- K. NISHIMUIRA, K. MIYATA ----	KOBE STEEL LTD., SUPERCONDUCTING & CYROGENIC TECHNOLOGY CENTER ---- TEKKO BLDG., 8-2, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- Y. KAWATE ----	Y A DT U	0.3 ---- MICROW AVE PLASMA CVD, DIAMON D FILMS	----	---- SEE MEMO	0800 ----	1332 ----	----	JDB/REV IEW 6/014 08/01/8 9 H182B / / JA
07040 10B07 A H174A DCF 51	B	MITSUBISHI PRODUCT DVELOPMENT LABRATORY ---- HYOGO, JAPAN ---- Y. GOTO ----	---- ---- ----	---- ---- ----	Y A DT U	06 ---- EXIMER LASER INDUCE D CVD	----	----	0800 ----	----	----	JBA/01- 01-89/0 11 01/01/8 9 H144B / / JA
07040 10B07 A H001E DCF 7	B	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIALS ---- TSUKUBA, JAPAN ---- M.KAMO ----	NATIONAL INSTITUTE FOR RESEARCH IN INORGANIC MATERIALS ---- TSUKUBA, JAPAN ---- S.MATSUMOTO ----	NATIONAL INSTITUTE FOR REASERCH IN INORGANIC MATERIALS ---- TSUKUBA, JAPAN ---- N.SETAKA ----	Y A DT U	05 ---- CVD METHOD S - HOT-FI LAMENT , RF-WAV E, MICROW AVE METHOD S	----	----	----	----	----	JAE/VOL 38 #6/4067 08/15/8 8 H005A / / JA

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07040 10B07 A H035A DCF 70	B	NIPPON INSTITUTE OF TECHNOLOGY, DEPT. OF ELECTRICAL ENGINEERING AND ELECTRONICS ---- MIYASHIRO, MINAMI-SAITAMA, SAITAMA 345, JAPAN ---- YOICHI HIROSE, SYUJI ANAMUMA, N. OKADA ----	SYOWA DENKO KK,CENTRAL RESEARCH LABORATORY ---- TAMAGAWA, OHTA-KU, TOKYO 146, JAPAN ---- KUNIO KOMAKI ----	---- ---- ----	Y A DT U	030 ---- COMBUS TION FLAME	----	----	0500 ----	01333 ----	----	JBS/ABS . 77/0114 04/24/8 9 H070A / / JA
07040 10B07 A H181A DCF 39	C	OSAKA UNIVERSITY ---- OSAKA, JAPAN ---- SEE COMMENTS ---- J. SUZUKI, H. KAWARADA, K.S. MAR, J.WEI, A. HIRAKI	---- ---- ----	---- ---- ----	Y A DT A	----	----	----	0600 ---- LOW PRESSU RE	----	----	JAJ/07-11-89/3 42 07/11/8 9 H183A / / JA
07040 10B07 A H181A DCF 62	C	OSAKA UNIVERSITY, FACULTY OF ENGINEERING ---- SUITA, OSAKA 565, JAPAN ---- H. KAWARADA, K.S. MAR & A. HIRAKI ----	---- ---- ----	---- ---- ----	Y A DT U	---- MAGNET O-MICR OWAVE PLASMA METHOD	----	080 ----	0800 ----	----	----	JAH/VOL 26 #6/L103 2 06/01/8 7 H028A 05/06/8 7 JA
07040 10B07 A H181A DCF 100	C	OSAKA UNIVERSITY, FACULTY OF ENGINEERING ---- SUITA, OSAKA 565, JAPAN ---- JIN WEI, H. KAWARADA, JUN-ICHI SUZUKI ----	OSAKA UNIVERSITY, FACULTY OF ENGINEERING ---- SUITA, OSAKA 565, JAPAN ---- AKIP HIRAKI ----	JAPAN SYNTHETIC RUBBER CO., LTD ---- ---- K. YANAGIHARA & K. NUMATA ----	Y A DT U	---- MAGNET O-MICR OWAVE PLASMA CVD	----	080 ----	----	----	----	JBS/ABS 106/015 4 04/24/8 9 H098A / / JA

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07040 10B07 A H034B DCF 103	C	SEIKO INSTRUMENTS INC. ---- 563, TAKATSUKA-SHINDEN, MATSUDO-SHI, CHIBA 271, JAPAN ---- A. NISHIKAWA & H. FUNAMOTO ----	NATIONAL RESEARCH LABORATORY OF METROLOGY ---- TSUKUBA, IBARKI 305, JAPAN ---- A. ONO & T. BABA ----	---- ---- ----	Y A DT U	---- MICROW AVE PLASMA CVD	030 ----	----	----	---- THERMA L CONDUC TIVITY STRONG LY CORREL ATES WITH RAMAN SPECTR UM	----	JBS/04-24-89/0 171 04/24/8 9 H113B / / JA
07040 10B07 A H027A DCF 61	B	TOKYO INSTITUTE OF TECHNOLOGY, RESEARCH LABORATORY OF ENGINEERING MATERIALS ---- 4529 NAGATSUTA, MIDORI, YOKOHAMA 227, JAPAN ---- TAKASHI KAWATO & KEN-ICHI KONDO ----	---- ---- ----	---- ---- ----	Y A DT U	0.5 ---- CVD WITH CH4 GAS MIXTUR E AND NO OXYGEN ADDITI VE	----	0850 ----	----	----	----	JAH/VOL 26 #9/1429 09/01/8 7 H027B 04/09/8 7 JA

** *************** SUB-TECHNOLOGY: DCF - PROCESS - SPOT

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
07040 10B08 A 175D DCF 46	C	KOBE STEEL LTD. ---- 5-5-1, 1-CHROME TAKATUKADAI, NISHI-KU, KOBE, HYOGO 673-02, JAPAN ---- DR. KOJI KOBASHI ----	---- ---- ----	---- ---- ----	N A DT U	---- EACVD METHOD WITH METHAN E CONCEN TRATIO N 3%, NO POLISH ING	060 ----	----	----	----	----	JAZ/FAX 12-13-8 8/01 12/13/8 8 H146A 12/13/8 8 JA

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07040 10B08 A 175A DCF 94	B	NIPPON INSTITUTE OF TECHNOLOGY ---- ?, JAPAN ---- PROF. YOICHI HIROSE ----	---- ---- ----	---- ---- ----	Y P RD U	----	----	0127.5 ---- 5"	0600 ----	----	----	JAK/VOL 7 #27/048 09/01/8 8 H178C / / JA
07040 10B08 A H177A DCF 90	C	OSAKA UNIVERSITY ---- OSAKA, JAPAN ---- PROF. AKIO HIRAKI ----	---- ---- ----	---- ---- ----	Y P RD U	---- LOW PRESSU RE METHOD	----	0100 ----	0700 ----	----	----	JAK/VOL 6 #23/05 08/01/8 7 H177B 08/01/8 7 JA
07040 10B08 A H186A DCF 78	B	SUMITOMO ELECTRIC INDUSTRIES LTD ---- 1-3, SHIMAYA 1-CHOME, KONOHANA-KU, OSAKA, 554, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	----	----	012 ---- LARGE SINGLE -CRYST AL	----	----	----	JAY/08-12-89/0 23 08/12/8 9 H173A 07/31/8 9 JA
07040 10B08 A H186A DCF 88	E	SUMITOMO ELECTRIC INDUSTRIES LTD ---- KONOHANA-KU, OSAKA 554, JAPAN ---- ---- SEE MEMO-INDUSTRIAL APPLICATIONS	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	----	----	----	JBD/08-14-89/0 8 08/14/8 9 H178A 08/14/8 9 JA

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07040 10B08 A 175D DCF 47	B	KOBE STEEL LTD. ---- 1-5-5 TAKATSUKADAI, NISHI-KU, KOBE 673-02, JAPAN ---- DR KOJI KOBASHI ----	---- ---- ----	---- ---- ----	N A DT U	020 ---- EACVD (HOT-F ILAMEN T WITH A DC BIAS), DURATI ON 33HRS.	070 ----	----	----	----	----	JAZ/FAX 12-16-8 8/01 12/16/8 8 H149A 12/16/8 8 JA
07040 10B08 A 175C DCF 48	C	KOBE STEEL LTD. ---- 5-5-1 1-CHROME TAKATSUKADAI, NISHI-KU, KOBE 673-02, JAPAN ---- DR. KOJI KOBASHI ----	---- ---- ----	---- ---- ----	Y A DT U	---- MICROW AVE CVD, 4 HRS	06 ----	----	0820 ----	----	----	JAZ/FAX -09-30- 88/01 09/30/8 8 H150A 09/30/8 8 JA
07040 10B08 A 175C DCF 49	C	KOBE STEEL LTD. ---- 5-5-1 1 CHROME TAKATUKADAI, NISHI-KU, KOBE 673-02, JAPAN ---- DR. KOJI KOBASHI ----	---- ---- ----	---- ---- ----	Y A DT U	---- MICROW AVE PLASMA CVD, DURATI ON 7 HRS	01.5 ----	----	0800 ----	----	----	JAZ/08- 16-88/0 1 08/16/8 8 H151A 08/16/8 8 JA
07040 10B08 A H178A DCF 92	C	NIPPON INSTITUTE OF TECHNOLOGY ---- SAITAMA, JAPAN ---- PROF. YOICHI HIROSE ----	---- ---- ----	---- ---- ----	Y A DT U	0200 ---- OPEN ATMOSP HERIC COMBUS TION METHOD	----	----	0600 ----	----	----	JAK/VOL 7 #27/048 09/01/8 8 H178B / / JA

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07040 10B08 A H183A DCF 107	B	SUMITOMO METAL MINING COMPANY ---- 1-3, OHTEMACHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- S. FUTAKI, K. SHIRAISHI, & S. MATSUMOTO ---- EXCERPT FROM ARTICLE WRITTEN BY AUTHORS	---- ---- ----	---- ---- ----	Y A DT U	---- HIGH-FREQUECY DISCHARGE METHOD (HF) - SEE MEMO FOR COMPARISON WITH DC METHOD	----	----	0700 ----	----	----	JCJ/09-29-89/001 09/29/89 H183B / / JA

Record#	PAGENO	DESCRAPPLC
56	H0000	DIAMOND COATINGS & FILMS

Diamonds occur in nature as individual crystals called stones. Synthetic diamond stones have been made since the mid 50's by a high pressure-high temperature process. Recent research in the Soviet Union and Japan has identified conditions in which diamonds can be made in the form of continuous coatings, much like a layer of lacquer, on a variety of solid substrates. The most popular substrate is a silicon wafer; the deposits can be several hundred micrometers thick and can cover an entire four-inch industrial silicon wafer of the type used in manufacturing integrated circuits.

The conditions required for diamond growth are relatively benign; substrate temperatures can be as low as 400 deg C and the gaseous environment surrounding the substrate can be from 30 to 300 Torr (1 atmosphere pressure m760 Torr). The gaseous environment surrounding the substrate is typically 97-99% hydrogen gas and 1-3% methane (CH4). The latter is the source of carbon atoms (diamond is pure carbon). The gas mixture is energized by microwaves at 2.45 GHz (same as a kitchen microwave oven) and roughly 300 watts. Deposits grow at a rate of about 1 micrometer per hour.

Films that don't adhere to the substrate are usable as diamond dust which is utilized in metal grinding and finishing operations. Films that adhere to the substrate but do not form a single crystal have many applications. The film can be used on many substrates, or by itself, as a highly transparent window that cannot be damaged by a laser. It can also be used for high temperature semiconductor substrates or super high intensity heat exchangers for arrays of light emitting diodes.

Films that adhere to the substrate and form a single crystal can be used to produce the finest transistor which is 8100 times better than silicon (measured by Keyes parameter) .

OTHER APPLICATIONS :

1. Cutting tool coatings
2. Optical coatings
3. Loudspeaker components
4. Prosthetic coatings

113 H190A Japan leads the world in diamond research. Domestic competition in developing diamond elements is strong, and universities and public and national laboratories are also participating in the study. Some researchers are pessimistic, claiming that diamond semiconductors will not be developed unless theie is a significant break-through. However, a trend for greater number of researhers is developing, making it more likely to find original ideas. The R&D for diamond elements is likely to be further accelerated.

10 H008A The growth of boron-doped diamond films, by plasma assisted CVD, with an electrical resistivity in the range of 0.001-1 ohm*cm was reported to be monocrystalline when deposited on a diamond substrate and polycrystalline when deposited on a silicon substrate.

67 H039A Diamond thin films were produceed by electron assistedchemical vapor deposition which was originally proposedby the present authors. The films were produced mainly onSiC with a high growth

rate (3-5 um/h) and at arelatively low temperature(823 K). The films obtainedare characterizd by electron and X-ray diffraction,electron energy loss spectrometry, Raman scattering,
laser microprobe mass analysis, secondary ion massspectrometry and IR absorption spectrometry. Theirgeneral properties such as hardness, thermalconductivity, specific gravity and electrical resistivityare also measured. From these results, diamond thin filmsfomed by electron-assisted chemical vapour deposition areshown to have almost the same characteristics as naturaldiamond.
The influence of the electron bombardment on the filmgrowth is discussed in relation to the decomposition ofreactant gases (CH4 and H2).

PROPERTIES OF DIAMOND THIN FILMS FORMED BY ELECTRON-ASSIATED CVD

THERMAL CONDUCTIVITY	WmK^-1	1100
SPECIFIC RESISTANCE		10^15
SPECIFIC GRAVITY		2.8
VICKERS HARDNESS		70000 - 10000

31 H156A Canon is the first company to succeed in observing the blue light emitted by artificial diamonds. The newly developed device is made of insulation films of oxide hafnium and alumina (0.2 micron thick each) on a silicon substrate topped with a 1-2 micron thick diamond thin film. The diamond thin film was formed

by the CVD method using a gas mixture of methane and hydrogen. Blue light of 435 nanometer wave length was emitted when a 150-250
V electrical charge was applied to the diamond thin film containing transparent electrodes. Blue light was emitted with both
A.C. and D.C. currents. Since artificial diamonds can be created

in many different shapes and because it is a simple device, prospects for application in EL devices is good once the light density increases and longevity advances.

111 H169A Firm Succeed in Development

Canon fabricated a polycrystalline diamond thin film by chemical vapor deposition (CVD) and used it in a blue light emitting element. This film does not contain any impurities, which usually cause light emission. Canon does not yet understand the light emitting mechanism. The firm will investigate this mechanism and plans to develop high performance elements.

115 H191B BLUE ELECTROLUMINENCE HAS BEEN OBSERVED IN THIN-FILMDIAMOND DEPOSITED ON A SUBSTRATE WHEN A MIXTURE OFMETHANE AND HYDROGEN GASES REACT UNDER HEAT TREATMENT BYTUNGSTON FILAMENT. THE DIAMOND ACTIVE LAYER IS SANDWICHEDBETWEEN METAL OXIDE INSULATING LAYERS, WHICH FORMED BYEVAPORATION IN METAL OXIDES IN OXYGEN PLASMA. INDIUM TINOXIDE FILM IS USED AS A TRANPARENT ELECTRODE. THEELECTROLUMINESCENCE SPECTRUM SHOWS THE PEAK AT 435nm ANDLUMINANCE IS 3.6 cd/m^2 AT APPLIED VOLTAGE OF 400V.

106 H184A THIS REFERENCE WAS TAKEN FROM AN ADVERTISEMENT IN THE"SCIENCE & TECNOLOGY IN JAPAN" JOURNAL. THE ADVERTISEMENTCLAIMS LOW PRESSURE LOW TEMPERATURE SYSNTHESIS OFDIAMONDS FOR USE ON TOOLS AND SEMICONDUCTOR DEVICES.

22 H001J Diamond-coated heat sinks require films with excellent thermal properties. In a study of the thermal properties of polycrystalline diamond, Akirc Ono and coworkers at the Japanese

National Research Laboratory of Metrology and Seiko Instruments correlated the thermal conductivity of microwave plasma deposited films with the methane concentration in the reactive gas. They find that only graphite-free films prepared with low methane concentration have the thermal conductivity of natural diamond.

117 H193A Diamond Thin Film by Seletive Aeea Vapor Deposition

Kobe Steel has established a selective area vapor deposition technique which achieves vapor deposition only in designated areas on a diamond thin film, by following a design pattern that is several micrometers wide (minimum). This technique can be used with either (1) the reactive ion etching (RIE) method, or (2) the amorphous silicon masking method, depending on the objective and process involved. A former selective deposition technique consists of using an Ar ion beam for sputtering instead of the reactive ion etching (RIE) method. However, when the Ar ion method is used, the directivity of the ion beam and the experimental parameters require precision control. On the other hand, theses issues are not involved in the RIE method, and high selectivity can be achieved. Using the RIE method, a diamond thin film pattern can be freely drawn on a silicon wafer. The achievement of semiconductor diamond thin film synthesis, together with this new technology, enables the manufacturer of a diamond semiconductor device that can range in size from several microns to several tens of microns. It is also possible to arrange these semiconductors freely in a high density configuration. This accomplishment leads to redevelopments in the field of microelectronics based on diamond thin film. Compared to silicon and gallium arsenide, diamond is superior with regard to resistance to heat, radiation, and chemicals. Because of its large band gap and electron hole transition performance, applications are anticipated in semiconductor devices used in aeronautics, spacecraft and automobiles.

53 H134A Form Diamond Circuit Patterns on Silicon: At last week's Japan Society of Applied Physics meeting in Chiba, Kobe Steel researchers told of two methods for forming polycrystaline diamond circuit patterns on silicon wafers. The diamond thin films have a number of advantages over conventional silicon and gallium arsenide: better heat and radiation resistance, better thermal conductivity, and a larger band gap for more electron mobility.
Both processes start with buffing a silicon substrate with a diamond paste to produce countless small flaws in the surface. Resist pattern is formed by conventional photolithography. Then processes diverge. In reactive ion etching (RIE) method, resist-patterned surface is etched with standard RIE equipment using a mixed plasma of argon, oxygen, and carbon tetrafluoride.

An organic solvent removes the resist and diamond is vapor-deposited. Diamond film forms selectively on areas that have been covered by the resist. In amorphous silicon masking (ASM) method, resist-patterned surface has amorphous silicon applied by chemical vapor deposition (CVD) equipment.

Kobe plans to use processes to make thermistors and Schottky

barrier devices. Over next five years it will develop a way to form single-crystal diamond circuit patterns on silicon.

64 H034A THERMAL CONDUCTIVITY OF DIAMOND FILMS SYNTHESIZED BYMICROWAVE PLASMA CVD

A measurement method is developed for the thermalconductivity of thin films in the direction paralleltothe surface. Measurements are made between 100 deg C and130 deg C for diamond films of 7um to 30um thick thatare synthesized from a gas phase of methane/hydrogenmixture by microwave plasma chemical vapor deposition.The thermal conductivity of diamond films increasesrapidly with decreasing concentration of methane. Thehighest thermal conductivity ever obtained in thisexperiment is about 1000 Wm^-1 K^-1. The thermalconductivity and Raman spectrum are compared underdifferent synthesis conditions.THERMAL CONDUCTIVITY OFDIAMOND FILMS SYNTHESIZED BY MICROWAVE PLASMA CVD

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55 H138A As part of an international race to develop new ways to make synthetic diamonds, manufacturers have begun to coat objects as diverse as drills and dentures with synthetic diamond films.

Scientists have demonstrated, moreover, that it is perfectly possible to make silk purses from sows'ears. A research group at Pennsylvania State University recently made synthetic diamonds using a common oxyacetylene welding torch. Earlier this year, Dr. Yoichi Hirose of the Nippon Institute of Technology in Sailama, Japan, created diamonds from sake(rice wine). Diamonds are a special form of carbon in which carbon atoms arrange themselves in an unnaturally cramped crystal structure. At normal pressures a diamond will revert to ordinary carbon after a period of a billion years or so.

107 D185A In the field of material sciences, it has long been desired to develope the equipment to obtain crystallographic information of micrometer-size crystalline substances. Synchrotron radiation (SR) could be a candidate to deal with such a small specimen other than electron microscope. It seems more advantageous to utilize SR from the viewpoint that the processing of the diffraction data that has already been established for identification of the materials, structure analysis, and refinement. Even in the case of SR, special care should be taken for the measurement of very weak diffracted intensities. In the case not using SR, the size of 50um might be the limit for the specimen to be examined by the diffraction method. The diffrlacted intensity is proportional to the volume of the specimen, and that of micrometer-size crystal is estimated as 10^-5 times of that of the limit mentioned above. The noise level ofthe experiment, therefore, should be as low as possible. If the noise level becomes negligibly small, the signal could be accumulated continually to the desired intensity level by adjusting measuring time. The experiment, for the purpose, should be carried out in vacuum with the stational crystal method and with very narrow collimated x-ray beams. The Laue method is employed by the above reason, as well as the fact that the

intensity of each Bragg reflection on a reciprocal row passing through the origin of the reciprocal space is superposed with each other, which also intensifies a diffraction spot on the photographic plate. The Laue camera is set up at BL-4B of Photon Factory, sealed in vacuum and installed with a very narrow collimater. The development of the system has been performed to the level which several Bragg reflections of molybdenum single crystal with 0.8 um in its diameter can be taken in the imaging plate for 50-min exposure with ring current from 128 to 125 mA. The origin of diamonds in meteorites has been a controversy as to whether they are formed from carbonaceous materials by impact shock or directly formed from vapor. Recent discovery of vapor-growth diamonds in carbonaceous chondrites has generated a renewed interest in the origin of ureilite diamonds. Two types of micrometer-size diamonds were prepared. One of them was grown under low pressure by chemical vapor deposition (CVD) from gaseous mixtures of H, and CH, and another was synthesized by shock effect (kindly offered by Nippon Oil & Fats Co., Ltd.) The micro-Laue method was applied to them in order to get information about their microstructures. Two characteristics are recognized in profiles of reflections themselves and in whole patterns of the Laue photographs. The reflections of CVD diamonds are elongated but symmetric in their profiles and are distributed regularly as they are indexed by the diamond lattice, while those of shock effect are also elongated and asymmetric, and are distributed at random as they cannot be indexed. The characteristics observed by the method may be useful to ascribe the origin to CVD or shock effect.

43 H167A Cathodoluminescence of Synthesized Diamond

A cathodoluminescence (CL) spectrum obtained from a diamond thin film produced by the microwave plasma CVD method has its peak in the range of 2.4-2.8 eV, and it can display either a green color or blue luminescence. This can be explained by the donor acceptor pair transition mechamism, which is similar to that of natural diamond or diamond synthesized at high pressure. The luminous field of a thin film sample having blue luminescence was reported at the previous meeting. Even in the case of the sample with blue luminescence, it was observed that the (100) plane radiated strongly, but the (111) plane did not radiate as much (Figure 1) [not reproduced]. The existence of a difference in luminescent strength of a growing plane at the level of individual particles corresponds to the results obtained when diamond is synthesized at high pressure. This sample was produced in conditions where there was less of a possibility that it could contain impurities.

A luminous spectrum has a strong peak in the blue field (Figure 2). Meanwhile, in the case of the sample doped with boron that becomes a p-type semiconductor, strong luminescence is observed.

100 H113A A measurement method has been developed for the thermal conductivity (λ) of thin

films in the direction parallel to the surface The method makes use of radiation heat transfer and radiation thermometry and enabled as to measure the thermal conductivity of diamond films, metal films and so on.

30 H124A Synthesis of artificial diamond film using a low-temperature, low atmospheric pressure vapor phase process has been gaining momentum, although at present thin film technology is still only used for plate coating.

Now Showa Denko has developed technology capable of producing 100%-diamond film with a curved surface as in a pipe and pot by crystallizing artificial diamond to a maximum of 100 um in thickness through a low-temperature, low atmospheric pressure vapor phase process.

The company's success in forming curved diamond film is a monumental achievement. In crystallization by conventional vapor phase processes, a few microns in thickness has been considered the upper limit. Furthermore, diamond film produced in this way has tended to crack after cooling due to the large thermal stress

resulting from the difference in thermal expansion between the base material and the diamond. With the new process, thermal stress is reduced and a film thickiness of 100 um can be achieved.

Because of this tremendous advantage, the technology is expected to find a broad range of mechanical, optical, audio, and medical applications such as in carbide tools, bearings, nozzles, thermoelectric materials, casings and other parts having curved surfaces, as well as speaker diaphragms and heat radiator boards.

PHYSICAL PROPERTIES	MEASUREMENTS
YOUNGS'S MODULUS	80-100 TON/mm^2
ELECTRIC RESISTANCE	.66 - 17x10^10 OHM CM
VICKERS HARDNESS	MORE THAN 10^4
REFRACTIVE INDEX	2.28 - 2.33

52 H127A Japan's Lead in Field

American experts acknowledge that Japan. now holds a commanding lead in "chemical vapor deposition" (C.V.D.) diamond technology. Statistics from industry sources provide a comparison: in the past five years, of 573 patents granted in the new diamond technology, 488 were awarded to Japanese companies and only 28 were awarded in the United States. Japan has also begun to exploit its research.

Two years ago, the Sony Corporation began marketing tweeter loud speakers incorporating very thin diamond resonators. The low

density and very high rigidily of diamond makes diamond films ideal
for the range of human hearing.

Japan's Asahi Diamond Industrial Company, the largest manufacturer of cutting bits in the world began six months ago to market ultrahard tools coated with vapor-deposited diamond.

E

Among the many large Japanese Companies investigating semiconductor applications of synthetic diamond are Fujitsu, Matsushita Electric Company, the NEC Corporation, the Seiko Instrument Company, and the Sumitomo Electric Company.

Butw while the United States still trails badly. American organiazations are rushing to catch up.

44 H168A Diamond Thin Film Thermistor

1. Introduction

Various studies about diamond thin films manufactured using the vapor-phase synthesis method are presently underway. Among them are a group focusing on the application of semiconductor materials. Diamond exhibits many interesting characteristics in terms of its electric properties. Since this material is electrically and chemically stable at high temperatures, it is expected that it can be used to produce heat-resistant devices. A thermistor has been experimentally manufactured from a polycrystalline diamond thin film. This will be discussed subsequently.

2. Sample Preparation

Figure 1 (not shown) shows the structure of the experimentally

manufactured diamond thin film thermistor. By using a base material such as AIN and Si3N4, polycrystalline diamond thin films both B-doped and nondoped were forned. An electrode was adopted to the three-layer structure of Au/Mo/Ti in view of the need for heat resistance. A Ni wire was used as a lead wire,

and it was attached with a silver paste for high temperature applications.

3. Evaluation of Characteristics

Figure 2 (not shown) shows an example of the resistance temperature
characteristics of the prototype thermistor in a range from room

temperature to 600"C. In the case of the thermistor made from a

B-doped film, its resistance varies from 10^2 to 10^4 ohms. Its B constant was about 2000. This thermistor can be used in the wide temperature range from room temperature to 600"C. The thermistor made from a nondoped film showed a high level of resistance, and its B constant was about 700.

109 H187A As with many other key technologies under study today. the Japanese have invested significant effort over the past several years in developing CVD diamond technology. Current estimates indicate that more than 100 Japanese organizations, corporations and rescarch institutions like are involved in some degree of research in CVD diamond films. And it's the major companies in Japan that are investing: Sumitomo Electric, Mitsubishi Metal, Asahi Diamond, NEC, Kyocera and Kobe Steel. to name just a few.

33 H158A The artificial diamond, which formed the core of cutting tools, has suddenly gained attention as a new electron material of the future. The reason is that, with electron the promising prospect of manufacturing a high-quality crystal thin film, it has a possibility for application as a semiconductor. At "The First New Diamond International Conference" held recently in Tokyo, successive announcements were made concerning application research on the diamond as a practical element for sensors and luminous diodes. The appearance of an element with superior performance in computation speed and environment-resistance compared to such previous materials as silicon is expected.

The artificial diamond was manufactured previously with a method that utilized superhigh pressure. It was difficult to produce a high-quality thin film with this method, and its uses were limited to such tools as drills, cutters and abrasives.

Recently, however, synthesis of a high-quality artificial diamond thin film became feasible, using a method called CVD (carbon vapor deposition) that does not use superhigh pressure. Consequently, attention has been focused on its functions, apart from its qualities as a semiconductor and its hardness that has good heat-conduction.

Chief researcher Naoji Fujimori of Sumitomo Electric Industries and his team have succeeded in producing a semiconductor thin film with the artificial diamond that is nearing practical application, and they have actually trial-manufactured a temperature sensor.

However, in order to apply them as full-fledged electron materials, the future task remains of monocrystallizing the thin film that is presently made up of polycrystals.

112 H189B Firm Succeed in Development

Sumitomo Electric Industries also used CVD for its lightemitting element. The company emphasizes the fact that it succeeded in making a single-crystal thin film of diamond. Although Sumitomo faied to get blue light, the company is convinced that single crystals are better for future applications, and plans to develop elements from manmade single crystals with few defects.

The development of elements, however, is merely the first step. Naoham Fujimori, a principal investigator in Sumitomo's Itami Laboratoty, emphasizes the fact that their final goal is a diamond semiwnductor by claiming everyone is working on the semiconductor; their is no good reason to begin research with light-emitting elements." Diamonds have the same crystal structure as that of silicon and gerananium, which are currently used as semiconductors. Diamonds have the potential of becoming the next generation semiconductor that can withstand harsh environments due to its characteristics. The diamond research of these companies aims at the development of an environment-resisting semiconductor, which is likely to have a large market in the future.

18 H001B

19 H001C BECAUSE DIAMOMD IS COMPATIBLE WITH BIOLOGICAL TISSUE, IT CAN ALSO BE USED TO COAT PROSTHETIC MATERIALS AND BIOSENSORS. SUMITOMO ELECTRIC DESCRIBES THE SUCCESSFUL IMPLANTATION OF A DIAMOND COATED HIP JOINT IN A RABBIT IN ONE OF ITS OVER 200 PATENT APPLICATIONS.

34 H158B The artificial diamond, which formed the core of cutting tools, has suddenly gained attention as a new electron material of the future. The reason is that, with electron the promising prospect of manufacturing a high-quality crystal thin film, it has a possibility for application as a semiconductor. At "The First New Diamond International Conference" held recently in Tokyo, successive announcements were made concerning application research on the diamond as a practical element for sensors and luminous diodes. The appearance of an

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The National Institute of Research on Inorganic Materials [NIRIM] of the Agency of Science and Technology has produced a luminous diode that emits ultraviolet using a CBN (Cubic Crystal Boron Nitride) thin film, in which nitrogen and boron form a diamond structure. It can reportedly emit a 215-nanometer (1 nanometer - 1/100 millmiter) ultraviolet ray with the shortest wavelength. With the use of this technology, the way will reportedly be opened to diamond luminous diodes.

However, in order to apply them as full-fledged electron materials, the future task remains of monocrystallizing the thin film that is presently made up of polycrystals.

42 H166A Film With Semiconductive Properties (III)

Regarding the synthesis of p-type diamond with semiconductor properties, sone results have been reported. However, there have been almost no studies about the synthesis of diamond having n-type semiconductive properties.

In this study, in order to synthesize n-type diamond, a compound containing chemical elements such as nitrogen(N) and phosphorus (P) was dissolved into a liquefied organic compound and then vaporized. Next, it was used as a reaction gas. As a result, with regard to several samples that were confirmed to be diamond by X-ray diffraction, it was found that they had n-type electric conductivity due to the Seebeck effect.

As an example, an SEM photograph of the surface of the sample that was obtained by the use of a mixed solution composed of H3 PO4 (phosphoric acid), CH3 OH (methanol) and (C2 H5) 20 (diethyl ether) is shown in Figure 1 [not reproduced]. The result of X-ray diffraction is shown in Tabl 1.

23 H155A Diamond Thin Film By Modified ID Method

A research group at Tokyo University of Agriculture and Technology, has succeeded in synthesizing a thin film using a modified ionization evaporation method that has a Vickers hardness of 6500, and heat conductivity and electrical resistivty that are close to natural diamond. A characteristic of the ID method is the ability to seperate and evaporate the impurities and soot emanating from the ionic sorce during the forming of diamond film. Another major advantage is the ability to easily perform synthesis under a low temperature of 300-400 degree C and barometric pressure of 1/1000 of atmospheric pressure.
The reason why a substance with such properties was not utilized

very much in the past is that diamond synthesis required a high temperature and high pressure and the fact that synthesis was not

easily performed with simple apparatus. The keys to promoting application of the diamond film are to develop crystallization similar to the natural diamond, and to simplify the synthesizing apparatus.

1 H0000 FILM DEPOSITION PROCESS - WAFER

Heated filament process for diamond film deposition permits low deposition rates (0.5 to 20 microns per hour) on relatively large substrates (20 x 20 cm) of the type useful in microcircuit wafer production. However the high quality films required for microcircuits seem to be limited to a typical rate of 1 micron per hour, and the surface area must be smaller than the 20 cm limit.

69 H042A Diamond thin films have been formed by the newly proposed electron assisted chemical vapor deposition onSiC with a high growth rate (3 - 5um/h). The obtained films have good crystallinity in the sense of electron and x-ray diffraction. Vicker's hardness of the films isabout 9000 kg/mm^2. The influence of the electronbombardment on the initial island density on thesubstrate surface and on the decomposition of thereactant gases (CH4 and H2) is discussed relating tothe growth process of the films.

68 H039B Diamond thin films were produceed by electron assistedchemical vapor deposition which was originally proposedby the present authors. The films were produced mainly onSiC with a high growth rate (3-5 um/h) and at arelatively low temperature(823 K). The films obtainedare characterizd by electron and X-ray diffraction,electron energy loss spectrometry, Raman scattering,
laser microprobe mass analysis, secondary ion massspectrometry and IR absorption spectrometry. Theirgeneral properties such as hardness, thermalconductivity, specific gravity and electrical resistivityare also measured. From these results, diamond thin filmsfomed by electron-assisted chemical vapour deposition areshown to have almost the same characteristics as naturaldiamond.

PROPERTIES OF DIAMOND THIN FILMS FORM BY ELECTRONASSISTED CVD

THERMAL CONDUCTIVITY	110
SPECIFIC RESISTANCE	>10^15
SPECIFIC GRAVITY	2.8
VICKERS HARDNESS	7000-10000

The influence of the electron bombardment on thefilm growth is discussed in .
relation to the decomposition of reactant gases (CH4and H2).

14 H022A AN INVESTIGATION WAS MADE IN THIS STUDY OF THE MORPHOLOGY AND GROWTH OF DIAMOND FILMS DEPOSITED ON SILICON FROM MICROWAVE-GENERATED PLASMA OF METHANE-HYDROGEN MIXED GAS. THE SURFACES OF THE FILMS SYNTHESIZED 7 HOURS AT DIFFERENT METHANE CONCENTRATIONS. AT 3% METHANE THE SUBSTRATE IS COVERED WITH DIAMOND GRAINS HAVING TRIANGULAR CRYSTALLOGRAGHIC FACES. AT 4% METHANE THE MAJORITY OF GRAINS CONTAINED SQUARE FEATURES. THE SQUARE FEATURE BECOMES MORE PROMINANT AS METHANE INCREASES TO ABOUT 1%. BEYOND 1% THE DENSITY OF THE SQUARE FACES DECREASES AND AT CONCENTRATIONS HIGHER THAN 1.6%, THE FILM SURFACE BECOMES TOTALLY MICROCRYSTALLINE. TO INVESTIGATE THE FILM GROWTH PROCESS, THE CVD SYNTHSIS WAS INTERRUPTED EVERY FEW HOURS AND THE SAMPLE WAS TAKEN OUT OF THE REACTION CHAMBER TO OBSERVE EXACTLY THE SAME POSITION USING SCANNING ELECTRON MICROSCOPE. IT IS THUS FOUND THAT DURING THE FILM GROWTH AT METHANE = 1.2%, THE SURFACE MORPHOLOGY UNDERGOES A CYCLIC EVEOLUTION OF THE HIGHER-ORDER

AND THE APPEARANCE OF SQUARE FACETS. PERHAPS THE FINAL GOAL OF THE SYNTHETIC DIAMOND INVESTIGATION IS TO FABRICATE SEMICONDUCTIVE DIAMOND DEVICES, AND THE STUDY OF MORPHOLOGY AND GROWTH WILL PROVIDE USEFUL KNOWLEDGE FOR THE NEW FIELD OF DIAMOND ELECTRONICS.

114 H191A BLUE ELECTROLUMINENCE HAS BEEN OBSERVED IN THIN-FILMDIAMOND DEPOSITED ON A SUBSTRATE WHEN A MIXTURE OFMETHANE AND HYDROGEN GASES REACT UNDER HEAT TREATMENT BYTUNGSTON FILAMENT. THE DIAMOND ACTIVE LAYER IS SANDWICHEDBETWEEN METAL OXIDE INSULATING LAYERS, WHICH FORMED BYEVAPORATION IN METAL OXIDES IN OXYGEN PLASMA. INDIUM TINOXIDE FILM IS USED AS A TRANPARENT ELECTRODE. THEELECTROLUMINESCENCE SPECTRUM SHOWS THE PEAK AT 435nm ANDLUMINANCE IS 3.6 cd/m^2 AT APPLIED VOLTAGE OF 400V.

74 H171A The Central Research Institute of Canon Inc. was successful in test-producing lumlinescent devices using diamond thin films Canon Inc. test-produced an electroluminescent type device of a double insulation structure with two HfO2, (insulating film) films sandwiching a multicrystalline undoped diamond thin film. The insulating layers have been used to withstand strong electric fields, similar to an EL device of ZnS. The luminescent layer of diamond was formed by the hot filament CVD method, and other layers were formed by the reactive vapor deposition (ion plating) method. Under voltage of 150 to 250V, the device luminensced with either direct current or alternating

current. The wavelength distribution shows a peak in the vicinity

of 430 nm. However, the luminance was low at 3.6 cd/m^2 and the life is as short as only 10 to 20 minutes.

13 H020A Diamond crystals were grown at room temperature by ion-assisted deposition. The bombardment of aragon and hydrogen ions plays an important role in the growth of diamond. In order to effectively study the effects of hydrogen ion bombardment, three types of film were deposited under different conditions.

a) Pure Aragon feed through the ion source
b) Hydrogen additionally fed through the vacum chamber
c) Hydrogen additionally fed through the ion source.

Diamond films could not be observed in films (a) and (b) which were deposited without hydrogen ion bombardment. In film (c) diamond took two types of crystalline form: cubic diamond and hexagonal diamond.

20 H001D

15 H024A DEPOSITION OF DIAMOND LIKE CARBON FILMS BY PULSED-LASER EVAPORATION

Pulsed-Laser evaporation was proved to be a useful technique in preparing hydrogen-free diamond-like films. The fact that this method was different from ordinary evaporation was evident by the

presence of ions in evaporated materials, which were responsible for the production of diamond-like films. The apparatus was simple, and with eximer lasers deposition occurred effficiently. The properties of the deposits depended on substrate sur face state and varied with substrate temperature. Studies of refractive indices, chemical resistance and others showed that the films deposited at a substrate temperature of 50 degrees C were diamond-like. Electrical resistivity and optical band gap were somewhat low as characteristics of hydrogen-free films. No crystallinity was observed in the deposits.

16 H024B DEPOSITION OF DIAMOND-LIKE CARBONS FILMS BY PULSED-LASER EVAPORATION

Pulsed-Laser evaporation was proved to be a useful technique in

preparing hydrogen-free diamond-like films. The fact that this method was different from ordinary evaporation was evident by the presence of ions in evaporated materials, which were responsible for the production of diamond-like films. The apparatus was simple, and with eximer lasers deposition occurred effficiently. The properties of the deposits depended on substrate surface state and varied with substrate temperature. Studies of refractive indices, chemical resistance and others showed that the films deposited at a substrate temperature of 50 degrees C were diamond-like. Electrical resistivity and optical band gap were somewhat low as characteristics of hydrogen-free films. No crystallinity was observed in the deposits. The films at room temperature were transparent but could be scratched easily with a steel needle.

8 H005B

12 H011A The bombardment of aragon and hydrogen ions plays an important role in the growth of diamond. In order to effectively study the effects of hydrogen ion bombardment, three types of film were deposited under different conditions.

a) Pure Aragon feed through the ion source
b) Hydrogen additionally fed through the vacum chamber
c) Hydrogen additionally fed through the ion source.

Diamond films could not be observed in films (a) and (b) which were deposited without hydrogen ion bombardment. In film (c) diamond took two types of crystalline form: cubic diamond and hexagonal diamond.

11 H009A This study has investigated luminescent properties of synthesized diamond films using cathodoluminescence (CL). The observed CL spectra can be classified as band A luminescence, which is commonly observed in all types of natural and high-pressure synthesized diamond. The peak of these spectra occur at different energies between 2.4-2.8eV (from green to pupie-blue by visual inspection). In the samples exhibiting the peak at 2.45eV, the (100) faces appear bright in visible luminscence, whereas the (111) faces are dark. These features are comparable to the luminescent properties of high-pressure synthesized diamond. In more than several examples, the CL peak occurs at 2.8eV. To the researchers it is speculated that the higher enery emission spectra are caused by lower nitrogen content of the diamond films.

5 H001G

28 H123A (Japan) Fujitsu Laboratories Ltd. has developed a new process designed to synthesize diamond film at a deposition rate of 180 microns an hour, 50 percent faster than current processes. The company estimates that it will take two years to prepare the process br industrial use. The process, called plasma jetting, is a sophisticated version of a vapor phase process and is expected to facilitate production of diamond films with large surface areas and complicated shapes.

21 H001I Researchers at Idemitsu Petrochemical in Japan find that a film deposited from 40% carbon monoxoide in hydrogen still exhibits a resonable Raman spectrum for diamond.

37 H161A

Microwave Plasma CVD Synthesis

1. Introduction

The synthesis of diamond by the microwave plasma CVD method with CO, and using the reduction mechanism as the synthesis mechanism, were proposed in the earlier third report. The effect of adding H_2O and O_2 to the CO was also discussed. At this time, the study result of the effect of a mixed gas with the use of CO, CO_2, and CH_4 as carbon resources will be

discussed.

2. Experimental Method

A microwave plasma CVD apparatus developed by the Inorganic Material Laboratory was used. The substrate was Si (100). The diamond synthesis was carried out under the following conditions: the temperature of the substrate and pressure was 900"C and 5.3 KPa, respectively, and CO, CO_2, CH_4, and H_2 were used as raw gases. Observation of the generated material was done primarily with a SEM. Raman spectrum analysis and X-ray diffraction were used for the evaluation.

3. Experimental Results

Figure 1 (not shown) shows Raman scattering spectra for the samples synthesized using both CO gas alone and a mixed gas of CO and CH_4 (density of carbon resources: 10 percent). Where the CO gas alone was used, a strong Raman spectrum showing the presence of diamond was observed. By contrast, however, when the mixed gas was used, there was little evidence of the strong Raman spectrum characteristic of diamond. When the mixed gas of CO and CH_4 (volume ratio of 1:1) (density of carbon resources: 10 percent) is used, it is obvious that the CH_4 tends to become graphite.

38 H162A Microwave Plasma Growth Mechanism

The authors have identified three stages in the process of diamond growth. These are 1) the formation of a small cluster after the collision and reaction of the raw gases, 2) the creation of a nucleus by the gathering of clusters generated during stage 1), and 3) crystal is growth by the absorption of clusters into the nucleus.

The authors have previously proposed the following reaction mechanism for a co + H_2 system that could occur in stage 1).
C4 that could be related to the growth of diamond among C clusters generated through the above reactions, the structure of the neutral body of the clusters and its energy were calculated. Furthermore, in order for a comparison to be made for the model, QMS and radiation spectrum analysis were conducted. The results

and comments will be reported in the presentation.

99 H106A Many CVD methods or diamond synthesis have been developed to improve the deposition rate. The electron assisted CVD is one or the modified hot filament CVD method and Ikegaya et.al. reported the method that was co-enhanced by hot filament and DC-plasma. In this report, the effects or the deposition condetion or co-enhanced CVD method, especially the pressure and the composition of reactant gas were studied and plasma emission spectra were observed.
Tungsten filaments were heated to 2100 C and a 10-100V DC was applied between filments and the substrate. The current density was from 0. 1 to 0.8 A/cm^2. The reactant gas consisted or CH, and H, introduced with a flow rate of 2 cm/min. and the substrate temperature was fixed at about 900 C.
The deposition rate rase up as the reaction pressure increased and as the CH, content increased. At the reaction Pressure or 300torr, the deposition rate was 8um/H. The quality or the obtained film became worse with the CH4 content increased and as seen through the Raman spectra, the peak at 1332m disapeared when the film was deposited from the reactant gas of 5% CH4 content.This tedency is the same as that or conventional rilament CVD, but a grater distance between filament and substrate is possible than with conventional filamet CVD.
The plasma emission spectroscopic study was successfully performed by this method, no emission could be detected from filament CVD. The intensity of the peaks assigned to atomic hydrogen from the spectra or this method seemed to be larger than that or the plasma of microwave plasma CVD. This suggests that hydrogen in this process is more highly activated than hydrogen in microwave plasma CVD. The relationship between characteristics or deposited diamond and spectra or plasma will be discussed.

40 H164A

Further Magnetic Field Experiment

1. Introduction

Because the synthesis of diamond thin films has generally been conducted at relatively high pressures (tens of torr), it has not

been possible to measure plasma density. However, the authors were able not only to synthesize a diamond thin film at low pressure (0.1 torr) by using a magnetic field microwave plasma, but also succeeded for the first time in measuring plasma density in the field where the diamond thin film was formed.

2. Measurement Method

Measurement was conducted using the double probe method. The electrical potential of two probes was floated, and placed at the location where a diamond thin film was synthesized. The voltage-current characteristics of the probes were then measured and the temperature of the electrons and plasma density were calculated. H2 and H2+CO (CO:5 percent) were employed as raw gases. The pressure used was 0.1 torr.

3. Results

Figure 1 (not shown) shows the relation between absorbed microwave electric power and plasma density and electron temperature. Diamond is formed even at 0.1 torr, but its plasma density is 10^10 - 10^11 cm^-3.

94 H075A SELECTED-AREA DEPOSITION OF CVD DIAMONDS

Introduction

When a continuous polycrystalline diamond film issynthesized on Si, it is customary to polish the Sisubstrate by diamond powder or paste to enhance the nucleation density. although the mechanism of theenhancement is under controversy. In this case, thesubstrate is covered entirely with diamonds. In orderto use diamond film for micro-electronic devices, it isnecessary to form micron-size diamond films on selectedareas. Such an attempt was made recently, a resistpattern was formed on a polished Si using aphoto-lithography technique, and an Ar ion beam wasirradiated to sputter unnecessary Si surface areas. Ause of such substrates resulted in a growthof polycrystalline diamond films on the pattern.

In this paper, a similar attempt was made using aphoto-lithography and plasma etching technique commonlyused for Si device fabrication proeesses, and a diamond deposition on selected areas of a few micrometerin size was achieved.

Results

Figure 1 (not shown) shows a diamond pattern ofseveral different sizes, and Fig.3(not shown) is amagnified view. From these, it is clearly seen that polycrystalline diamond films can be deposited uniformlyand highly selectively on the desired area with only afew diamonds on unnecessary areas. Such a highselectivity was attained by the plasma etching methodused in the present work. Finally, it should be emphasized that the selected-areadeposition of diamond can be attained using a standard etehing technique used for Si device fabrications, andthe present technology will be useful in applications ofdiamond films for electronic devices.

96 H081A THE ANALYSIS OF DEFECT STRUCTURES AND SUBSTRATE/FILMINTERFACES OF DIAMOND FILMS

Diamond is an excellent candidate material for use innumerous electronic and wear resistant coatingapplications. The current emphasis on obtainingelectron-grade diamond films can be understood in termsof the many potantial applications which arise from itsexceptional electronic, thermal and mechanicalproperties. In the research described below, the diamondthin films have been characterized primarily by SEM andlow and high resolution TEM.

97 H089A CVD SYTHESIS OF (110)-ORIENTED BILAYER DIAMOND FILMS

In this study, in order to increase the nucleationdensity of diamonds, the Si substrates were polished by adiamond paste for 1h before film deposition. It was foundthat diamond films overgrown on a microcratalline filmwere strongly oriented with (110) planes of diamondsparallel to the substrate surface.

79 H175A

80 H175B

102 H182A Two kinds of hard carbon films, diamondlike carbon (DLC) and diamond, were synthesized by means of the radio-frequency (RF) and microwave plasma chemical vapor deposition methods, respectively. The synthesized films were characterized with electron microscopy, electron diffraction, and infrared Raman spectroscopy. It wasfound that the DLC films consisted of amporphous carbonwith 10 - 30 at. % hydrogen. On the other hand, thediamond films consisted of polycrstalline diamond and asmall amount of amorphous carbon and graphite, includingonly about 3at.% hydrogen. Higher growth rate in a 5cmarea will be realized in the near future by a newmicrowave CVD system originally developed by Kobe Steel.

EXPERIMENTAL CONDITIONS & APPLICATIONS

	DLC FILMS	DIAMOND FILMS
CVD METHOD	RF PLASMA CVD	MICROWAVE PLASMA CVD
SOURCE GAS	ETHYLENE	METHANE
PRESSURE	5 Pa	3.9 kPa
SUBSTRATE TEMP.	200 DEG C	800 DEG C
POWER	RF 100W	MW 300W
SUBSTRATE	Si	Si
COATING AREA	7 cm dia	2cm x 1 cm
MAJOR COMPONENTS	AMORPHOUS	DIAMOND
MINOR COMPONENTS	GRAPHITE & DIAMOND	AMORPHOUS & GRAPHITE
HYDROGEN CONTENT	10-30 AT %	3 AT %
APPLICATIONS	HARD COATING FOR ·MAGNETIC DISK, A-SI, PHOTO-RECEPTIVE DRUMS AND SOLAR CELLS. OPTICAL COATINGS	HARD COATING CUTTING TOOLS AND SPEAKERS DIAPHRAMS. HEAT SINKS. HIGH-PERFORMANCE ELECTRONIC SENSORS AND DEVICES.

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63 H032A Diamond thin films have been formed buy dc plasmachemical vapor deposition with a high growth rate (20um/h). The diamond has been grown from methane (CH4)and hydrogen (H2) mixed gases on Si and a-Al2O3 substrates at a pressure of 200 Torr without surfacescratching by diamond or c-BN powder. The obtained filmshave good crystallinity in the sense of electron andx-ray diffraction. Vicker's hardness of the film is thesame as that of natural diamond (10,000 kg/mm2).

78 H174A Diamond films
The session included a paper by Y.Goto and others, Mitsubishi Product Development Laboratory, Hyogo, Japan, on diamond-film deposition using laser-induced CVD. The system uses CCl, + H2

gases over the substrate, irradiated with a 193-nm ArF eximer laser. This gas mixture was chosen instead of CH4 because it absorbs the wavelength more efficiently, the binding energy is more appropriate, and it forms reactive radicals.

The 80-200-mJ pulses, each 50ns long, give a maximum growth rate of 6um/h. Raman spectroscopy shows that films grown without H2 include graphite. For films grown with atomic hydrogen, a Raman shift of 1333cm^-1 indicates that the films are diamond with no graphite.
Using laser power of 8W, the researchers determined that the

maximum deposition rate occurs at 800 deg. C. They beleive that the surface of the film is photoreactive and that the activated H2 increases the amount of carbon available for the diamond film.

51 H144B EXCIMER LASERS DEPOSIT DIAMOND-LIKE FILMS

Two papaers at the Annual Meeting of the MaterialsResearch Society, November 28 - December 2 in Boston,Mass., dealt with laser deposition of diamond films.

Y.Goto, Mitsubishi Product Development Laboratory, Hyogo, Japan, described the making of diamond films byexcimer-laser-induced chemical vapor deposition (CVD). An ArF laser beam reacted with CCl4 + H2 gases Flowing over the substrate. At 800"C, the deposition rate was6um/h.
J. Krishnaswamy and others at North Carolina StateUniversity, Raleigh, presented a late paper on deposition of hard, amorphous diamond-like @ilms by laser evaporation at temperatures between 50"C and100"C. The films were deposited at a rate o@ 0.1 nm per 40-ns pulse @rom a308-nm XeCl laser rocused

3 H001E

7 H005A Setaka and colleagues found using three different chemical-vapor-deposition methods, diamonds can be grown from a methane-hydrogen mixed gas on various substrates such as silicon, and of course on bulk diamonds, at a rate of about 0.3-0.5 microns per hour. X-ray and electron diffraction, Raman scattering, and other analyses indicate that the properties of the CVD diamonds are very similar to those impurity-free, type-IIa bulk diamonds. This finding instigated extensive on the CVD synthesis of diamonds in Japan.

93 H179A Large-Area Uniform Thin Film

The National Institute for Research in Inorganic Materials (NIRIM) of the Science & Technology Agency announced in November 1988 that it had developed a large-area diamond thin film of uniform composition and thickness. This circular thin film has a diameter of roughly 10 cm, and was produced by a process called microwave plasma CVD developed at NIRIM. It has about the same heat conductivity as natural diamond, and is considered to be a major contribution toward the commercialisation of diamond thin film.

In the new process, methane gas at a concentration of less than 1% is used as the raw material, a plasma is generated with a microwave of about 500 W, and artificial diamond is produced by gaseous phase growth on a silicon substrate in a low-pressure environment. Various methods can be used for exciting the gas or for heating the substrate, such as the microwave plasma method described here or other methods such as a hot filament, electric furnace, high-fequency plasma, DC plasma or burner, with each of these methods having its characteristic merits and demerits.

For example, a uniformly thick film can be produced by the microwave plasma method, but since the film's size is determined by the plasma width, films of large area cannot be produced.

To cope with this problem, NIRIM used two 1.5kW microwave generators and, by counterfacing them on a horizontal plane, developed a system to control the outputs of the generators and move the generated plasma's

position flexibly, which led to the generation of large-area films. The 30mm wide, 150 mm long plasma moves in the direction of the plasma's width. The generated plasma is highly stable, so diamond crystals are very uniform, and NIRIM announced that by passing 100-200 cm^3 of gas (methane gas of about 1% concentration), a diamond thin film can be grown at a rate of 0.2 um/h. This diamond thin film is a polycrystal body having a specific gravity of 3.52 g/cm^3 and a hardness of 8,000 kg/mm^2, the same as that of natural diamond.

A distinct advantage of this film is that it is very uniform, so many identical films can be produced with areas twice as large as those produced by conventional methods. A large-area diamond thin film manufacturing process based on the CVD method has already been used that heats the gas to 2,000 C by using hot filaments, but the new process provides much more uniform films and excellent re-producibility, so great expectations are placed on the application of this process by industry.

65 H034B THERMAL CONDUCTIVITY OF DIAMOND FILMS SYNTHESIZED BYMICROWAVE PLASMA CVD

A measurement method is developed for the thermalconductivity of thin films in the direction paralleltothe surface. Measurements are made between 100 deg C and130 deg C for diamond films of 7um to 30um thick thatare synthesized from a gas phase of methane/hydrogenmixture by microwave plasma chemical vapor deposition.The thermal conductivity of diamond films increasesrapidly with decreasing concentration of methane. Thehighest thermal conductivity ever obtained in thisexperiment is about 1000 Wm^-1 K^-1. The thermalconductivity and Raman spectrum are compared underdifferent synthesis conditions.

25 H154A Assistant Professor Yoichi Hirose and his team at the Nippon Institute of Technology have developed a new method of fabricating a diamond thin film at high speed. The maximum growth speed of the film is the fastest of all thin-film producing methods. The film quality is good, and it reportedly has a hardness that nearly equals that of natural diamond. Possible applications may be expected for the development of diamond semiconductors that can be used under such adverse environments as high temperatures, and for the coating of superhard industrial tools.

The new fabrication method is called arc electrical discharge plasma CVD [Chemical Vapor Deposition], which uses the high temperture of a direct-current electical discharge that reaches to about 5000"C. In addition to ethyl alcohol, such raw materials

as hydrogen and discharge-stabilizing argon gas are injected into

low-pressure container, dissolved at the electrical discharging section, and sprayed on a silicon substrate.

Only the carbon obtained from the ethyl alcohol is reportedly accumulated into a diamond form to produce the thin film. The speed is 4 to 5 times the speed of other thin fillm growth methods like microwave plasma CVD and high-frequency plasma CVD. It also surpasses the 200 microns of a high-speed thin film making process previously developed.

Another trait is the low amount of impurities that tend to occur during diamond synthesis, such as graphite an noncrystal carbon. This results in the formation of a thin film that is close to the

Recently, the synthesis of diamond by Chemical Vapor Deposition have been attracting interest of so many investigators. The synthetic diamond, by conventional low pressure CVD method in general contain non-diamond carbon, i.e diamond like carbon. However from the viewpoint or applications, the diamonds with less non-diamond are more desirable.
Recently, we have confirmed the growth of diamond, on substrates in combustion inner flame of various gases such as acetylene (C_2H_2), ethYlene (C_2H_4), propane (C_3H_8) etc in the atmosphere.
In this paper, the synthesis of very high quality and optically transparent diamond crystals using oxygen-acetylene combustion flame was tried. And the SEM micrographic observation, Raman spectroscopy and the emission spectroscopic analysis on the flame wasmeasured. Consequently, to reduce the degree of defect in crystals, the lowering crystal growh temperatures or substrate temperatures is essential. It is quite reasonable that high quality diamond can be obtained under conditions of low crystal growth rates.

35 H159A

Diamond Synthesis by Combustion Flame

[Text] 1. Introduction

Diamond is very useful as an engineering material, and it is essential to modern industries. The characteristic common to the traditional vapor methods is that the plasma used in the reducing ambience contains carbon atoms and carbon radicals. Since a combustion flame is a sort of plasma, we surmised that diamond can be synthesized with the use of a combustion flame. In our experiment we attempted to synthesize diamond by using an acetylene-oxygen flame in the atmosphere. Here, we present the conditions for synthesizing diamond, the characteristics of this method, and its application.

2. Synthetic Method

Figure 1 shows a) the combustion state of the acetylene-oxygen combustion flame used in this experiment, and b)the process of how diamond is synthesized. The combustion flame consists of an inner flame, or incomplete combustion area, and an outer flame, or complete combustion area. In the complete combustion area, all carbon atoms (C) are converted into carbondioxide (CO_2), The inner flame is also called the reducing flame. We surmised that there are carbon atoms and hydrocarbon radicals that could serve as the core of a diamond in the inner flame, and placed a substrate in it. Table 1 shows the typical conditions for synthesis.

Table 1. ExperimentAl Conditions

Ambience	In the air (in the atmosphere)
Pressure	Atmospheric pressure
Reaction gas	C_2H_2 + O_2
C_2H_2 (l/min)	1-4
O_2 (l/min)	0.5-4
2/C_2H_2	<=1
Substrate	Si, SiC, AL_2O_3, W, WC (containing Co),m
Substrate temperature ("C)	600-1100
Combustion flame temperature ("C)	2500-3000

3. Experimental Results and Discussion

We confinned with a scanning electron microscope (SEM) and X-ray diffraction that particles and thin layers of diamond were synthesized by using a combustion flame. We also confirmed by Raman spectroscopic analysis that the quality of the diamond synthesized was excellent. Although the synthetic mechanism is not yet fully understood, it was recognized by plasma emission analysis that there were C2 and CH radicals in the combustion flame. Since the adhesion of diamond on curved faces and concave and convex faces is very firm in the combustion flame method, we experimentally applied a coating of diamond on the surface of hard ultra-hard tools.

39 H163A Growth in Magnetic Field

1. Introduction

It was previously reported that it is possible to form a unifonn

diamond thin film even at the low pressure of 0.1 torr in the presence of CO by introducing a magnetic field, and that it is also possible to reduce the temperature of a substrate. At low pressure, specifically in order to prevent the generation of SiC,

a positive DC bias was impressed on the substrate. The relation between the impressed DC bias voltage applied to the substrate at low pressure and the subsequent product was investigated at this time.

2. Experimental Method

A Si wafer processed by supersonic waves and a diamond grinding compound was used as the substrate. The conditions of the experiment were as follows: CO/H2 density: 1-5 volume percent,

total flux: 100 SCCM, temperature of the 800-1000 W, and bias voltage: -60-+50V.

3. Experimental Results

Products varied greatly depending on theimpressed bias voltage of the substrate. Where the pressure was 0.1 torr and the temperature of the substrate was 750"C, diamond was formed when a positive bias was impressed on the substrate. However, in the case of grounding, diamond with RHEED orientation was formed. When a negative bias was impressed, SiC was formed at -10V, and there was no product formed at -60V, but many flaws were observed on the Si wafer. Figures 1 and 2 [not reproduced] show SEM images for the cases of +12.5V and grounding, respectively. These results suggest that electrons and ions exert a great influence on the formation of diamond at low pressure.

58 H181A Diamond films have been obtained using magneto-microwave plasma assisted CVD at 0.1 Torr. The reaction gas is a CO/H2 mixture. By setting the ECR condition at the deposition area, a high density plasma (1 x 10^11 cm^-3) is obtained around the substrate. The discharge area is quite uniform in the pressure. Diamond films are obtained on positively biased substrates. As the reaction pressure becomes lower, the substrate temperature for the diamond formation tends to decrease. The films were evaluated by SEM imaging, electron diffraction and Raman spectroscopy.

62 H028A LARGE AREA CHEMICAL VAPOR DEPOSITION OF DIAMOND PARTICLESAND FILMS USING MAGNETO-MICROWAVE PLASMA

Large area chemical vapor deposition of diamond has beenobtained

using magno-microwave plasma. The importantpoint of the developed system is to set the electroncyclotron resonance condition (875G) where the highestplasma desity is expected, at the deposition area bycontrolling the distribution of an applied magneticfield. Even in 10 Torr where complete electron gyrationscannot be expected, the size of the discharge areacontrolled by the magnetic field is 70-80mm in diameter.This value is the largest of all plasma depositionsystems of diamond. The crystallinity obtained by theabove-mentioned plasma compares favorably with those ofthe best ones by previous methods.

95 H076A SELECTIVE NUCLEATIONS OF DIAMOND PARTICLES BY PLASMAASSISTED CVD

Having the extra-ordinary properties such as wide bandgap and high thermal conductivity, synthetic diamond thinfilms are prospective for facbricating high temperaturesemiconducting devices. Until now, only homoepitaxialgrowth has been succeeded. Diamond thin films onhetro-substrates such as Si, SiO2, cet. ispolycrystalline. Based on our observation of ulta highvoltage transmission electron microscope on diamondparticles from cross sectional view, we have found thatdiamond nucleates at one size and then growsconcentrically to form a polyhedron with distinct facets.However these particles nucleate randomly so that theobtained film has different grain sizes. It has disadvantageous in using as semiconducting devices. In thisstudy diamond particles are formed at desired site,namely selective nucleation has been obtained. Thisselective growth of diamond leads to get uniformpolycrystals which are composed of large particles withthe same grain size, and it may be the nearest path toapply diamond thin film to semiconducting devices.

98 HC98A INTRODUCTION;

Diamond films have been formed by plasma CVD etc. However, by these methods, diamond films are formed inhigh pressure of 20-200Torr. We have applied magneto-microwave plasma CVD system for lower pressure(0.1-0.01Torr) deposition of diamond. At the lower pressure, we have measured for the first time the plasma density during the deposition of diamond. For the precise measurement, double probe technique has beenused. This technique has the following two advantages in the plasma under intense magnetic field. 1) The monitored currents are due to ions which are not effectedby the applied magnetic field. 2) The two probes areelectrically floating and has same surface areas. Thus, the effect of secondary electrons which are detrimental to the precise measurement of ion current has beencanceled. At 0.1-0.01Tor the critical density for the formation of diamond is about 2-3x10^10cm^-3. About 1x10^11 cm^-3, good crystals having (111) facets havebeen obtained. The crystallinity is highered inaccordance with the increase in plasma density during the depositions.

Results and Discussion:

The features of the discharge area strongly depend on pressure. In 10Torr the discharge is located around thesubstrate. The discharge area is about 70-80mm indiameter. On the other hand, at the lower pressure of0.1-0.01Torr, the discharge area is full of thecylindrical reaction chamber, plasma density is measuredby the double probe technique. It is as high as1x10^11cm^-3 around the substrate. At the magnetic field higher(P.)than ECR condision(P.), the higher plasma density has been measured than at the ECR condition . This means that discharge occurs predominantly by off-resonance mode, not by electron cycrotron resonance. The plasma density increases as increasing input microwave power. The deposition rate increases as increasing input microwave power. We supposethat the plasma

density is higher when the inputmicrowave power is higher. And high quality diamond isalso obtained at higher input microwave power.

At lower pressure (0.1-0.01Torr), the synthesis ofdiamond films depend on the substrate potential. Diamond films are obtained only on positively biased substrate. However, SiC is formed when the substrate is negatively biased to about 10V and the substrate is sputtered when the substrate is negativety biased to 60V. Accelerlyions at ion sheath are easily attracted to the substrateat lower pressure. Ions sputter the Si surface, SiC is formed. When the substrate is positively biased, ions can not attracted to the substrate and as a result onlydiamond is formed.

27 H122A In a separate development, tne Science and Technology Agency's National Institute on Research on Inorganic Materials has created a diamond thin film approximately four inches in diameter with uniform composition and a thickness of about 4 microns. Its hardness, specific gravity, and thermal conductivity are almost the same as natural diamond. The microwave plasma chemical vapor deposition method used to create the film allowed the diamond to grow steadily for several weeks, resulting in production of quality film. Reproducibility is said to be excellent. The achievement is considered a major step toward diamond film applications in semiconductors, heat dissipating substrates for VLSI circuits, and tools for machining very hard materials.

101 H113B A measurement method has been developed for the thermal conductivity (A) of thin films in the direction parallel to the surface. The method makes use of radiation heat transfer and radiation thermometry and enabled as to measure the thermal conductvity of diamond films, metal films and so on.
*****SEE H113A**********

29 H124A Synthesis of artificial diamond film using a low-temperature, low atmospheric pressure vapor phase process has been gaining momentum, although at present thin film technology is still only used for plate coating.

Now Showa Denko has developed technology capable of producing 100%-diamond film with a curved surface as in a pipe and pot by crystallizing artificial diamond to a maximum of 100 um in thickness through a low-temperature, low atmospheric pressure vapor phase process.

The company's success in forming curved diamond film is a monumental achievement. In crystallization by conventional vapor phase processes, a few microns in thickness has been considered the upper limit. Furthermore, diamond film produced in this way has tended to crack after cooling due to the large thermal stress resulting from the difference in thermal expansion between the base material and the diamond. With the new process, thermal stress is reduced and a film thickiness of 100 um can be achieved.

Because of this tremendous advantage, the technology is expected to find a broad range of mechanical, optical, audio, and medical applications such as in carbide tools, bearings, nozzles, thermoelectric materials, casings and other parts having curved surfaces, as well as speaker diaphragms and heat radiator boards.

32 H157A The Sumitomo Chemical Company has developed a diamond thermistor as a temperature-measuring device at high temperatures that can measure a previously unmeasured domain. Its main feature is its ability to measure a broad domain from room temperature to 600"C. Applying vapor synthesis technology for diamonds, it utilizes past results on the control of the diamond's resistance rate and electrodes and the prospect of practical application has been confirmed. Uses for such machinery and facilities as internal combustion engines and chemical plants that are accompanied by high temperatures are conceivable. There is also the possibility of measurement at high temperatures, and studies will be made in this regard, together with a protective film for anti-oxidization.

a thermistor is a device that measures according to temperature changes and resistance values. It is currently used widely in such home electrical appliances as hot-air heater and refigerators, as well as for temperature compensation of curcuits contained in those equipment. The temperature-measuring thermistor is used by selecting materials that transmit electricity according to the temperature domain used. Although carbides in the non-oxide group are used for high temperatures, it is difficult to control the electncal properties and the upper temperature limit is about 400"C.

In comparison, since the diamond has a large band gap, the farication of a device for high temperature use is possible; and reseach is being conducted from this standpoint.

Sumitomo Chemical has used the vapor deposition method in conducting research on epitaxial growth and doping of the monocrystal diamond, and has obtained results concerning the control of the diamond's resistance rate and electrodes. The thermistor that was trial manufactured by applying the diamond's vapor deposition technology has a silicon nitride base, on which a diamond film (polycrystal film) made from doping boron was formed by microwave plasma CVD [Chemical Vapor Deposition]. The boron-doped diamond film becomes the layer that transmits electric current. The layer thickness is between 1 to 3 microns.

The electrode has a three-layer structure consisting of previously-developed gold-molybdenum-titanium, and was formed by the ion-plating method. Nickel was used for the lead line and affixed with silver paste. Since the diamond will oxidize from oxygen in the air, silicon oxide was formed as a protective film.

The resistance value changes in a straight line from room temperature to 600 degrees C, and its superior qualities are clearly shown. Not only can the resistance value be changed by altering the boron content, but the resistance value can also be easily detennined by changes in configuration.

36 H160B Microwave Plasma CVD Growth

[Text] 1. Introduction

According to conventional wisdom, H_2 is necessary for creating diamonds by vapor phase synthesis. However, Hirose et al. reported a diamond synthesis method using a combustion flame without the addition of H_2 in the spring of 1988. The authors recently succeeded in the synthesis of a diamond by using an O_2-CH_4 reaction gas system with no addition of H_2 in the microwave plasma CVD method.

2. Experimental Method

The experiment used a microwave plasma CVD apparatus. Si(100) was scratched by diamond powder and processed. It was then used as a basic material.

3. Experimental Results

Figures 1 and 2 [not reproduced] show the Raman spectrum and surface scanning electron microscope (SEM) image of the film that was grown under the following conditions: ratio of CH_4 to O_2: 1.5, pressure: 80 torr, microwave output: 380 W, temperature of the substrate: 900"C, and growth time: 1 hour. The sharp Raman spectrum characteristic of diamond is observed at 1333 cm-1 and it can be said that this indicates a good quality diamond film. With regard to the effect of the ratio of CH_4 to O_2, crystallization is best when the composition ratio of CH_4 to O_2 is 1.5. When this ratio becomes larger, the amount of separation in an amorphous phase becomes larger. On the other hand, when the ratio becomes smaller, growth speed slows. The growth speed of the film was observed to be about 2-3 um/h. The growth conditions and the characteristics of the grown film will be reported subsequently.

17 H001A
60 H027A EFFECTS OF OXYGEN ON CVD DIAMOND SYNTHESIS

In order to investigate the influence of oxygen on thechemical vapor deposition (CVD) of diamond, gas mixturesof H_2-CH_4 and H@-CH_2-O_2 were used to carry out normalCVD. The effects of the oxygen additive were examined bygas chromatography for the exhaust gas and by thecharacterization of the deposits. With the addition ofoxygen, the deposition of graphite or amorphous carboncould be surpressed, so that the growth rate of diamondwas extended. The effects resulted from the fact that theacetylene concentration in a deposition chamber issignificantly reduced upon the addition of oxygen.

61 H027B SEE PAGE NO H027A FOR DESCRIPTION OF THIS STUDY
24 H155A Diamond Thin Film By Modified ID Method

A research group at Tokyo University of Agriculture and Technology, has succeeded in synthesizing a thin film using a modified ionization evaporation method that has a Vickers hardness of 6500, and heat conductivity and electrical resistivty

that are close to natural diamond. A characteristic of the ID method is the ability to seperate and evaporate the impurities and soot emanating from the ionic sorce during the forming of diamond film. Another major advantage is the ability to easily perform synthesis under a low temperature of 300-400 degree C and barometric pressure of 1/1000 of atmospheric pressure.
The reason why a substance with such properties was not utilized very much in the past is that diamond synthesis required a high temperature and high pressure and the fact that synthesis was not

easily performed with simple apparatus. The keys to promoting application of the diamond film are to develop crystallization similar to the natural diamond, and to simplify the synthesizing apparatus.
The modified ID method consists of placing a magnet beside the ionic source of a conventional ID method device. Only the ionized methane molecules in the gas emmited from the ionic source by the magnet's field effect are deviated. Consequently, diamond film is formed by seperating and evaporating the impurities and soot emenating from the ionic source.

2 H0000 SPOT FILM DEPOSITION PROCESS

Direct current plasma jet process focuses coating on small area of substrate. Glowing plasma jet of direct current arc discharge can quickly deposit diamond film over a small (5mm x 5mm) area at growth rates of over 500 microns per hour. Temperature of plasma jet is several thousand degrees C and substrate must be cooled to below 1000 degrees C.

9 H005C

45 H169A Features of Needle-Like Diamond

1. Introduction

Many defects can usually be seen in a diamond film synthesized by the vapor-phase method. When a Raman spectrum is used, not only the spectrum for diamond, but also a spectrum peak due to a double bonding of carbons is often observed. In addition, the width of a Raman spectrum for synthesized diamond is wider than that of natural diamond by two to three times, and its peak value is naturally shifted to the high-frequency region. In this experiment, a needle-like diamond that showed almost the same Raman spectrum width as a natural diamond, and is also thought to

be composed of a single crystal, was obtained.

2. Experiment

A diamond film was synthesized by the microwave plasma CVD method.
This diamond film was etched in air plasma, and a needle-like diamond was obtained.

3. Results

Photograph 1 [not reproduced] shows an SEM image of the diamond film cross section indicating the (100) orientation obtained in this experiment. The microscopic Raman spectrum for this film has a narrow line width, and also agrees well with the peak location of a natural single crystal. It was confirmed through SEM observation that the needle-like diamond obtained in this experiment was a single crystal with fewer defects .

26 H122A The Kanagawa Prefecture Industrial Laboratory recently succeeded in depositing a polycrystalline diamond thin film on a one-inch silicon substrate using the "EACVD" method (probably designates electron-activated

or plasma-assisted chemical vapor deposition), claiming to have achieved a crystalline structure closer to that of natural diamond than any produced to date. The film was grown without abrasion treatment of the silicon substrate. The gas inlet and exhaust openings were sealed after the container reached a specified pressure, then the film was deposited.
Molybdenum, tantalum, and silicon nitide can also be used as substrates, allowing broader applications.

46 H148A
47 H149A Dr. R. H. Chatt
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12/16/88

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Dear Dr. Chatt,
Enclosed here is a thick diamond film deposited on Si with micropits on. The deposition was carried out by an EACVD (hst filament with a DC bias) apparatus for 33h using a methane (3%)-hydrogen mixed gas at 30 Torr. The estimated film thickness is 70 microns as the average growth rate of the apparatus is about
Merry Christmas and a Happy New year!

Sincerely yours,

K Kobasi

48 H150A Dr. R. H. Chatt
Directar Asia/Pacific
TRW Space & Defense Sector
One Space Park
Redondo Beach
CA 90278

September 30, 1988

Dr. Koji Kobashi
Senior Researcher
Electronics Technology

center

Kobe Steel, Ltd.
1-5-5 Takatsukadai
Nishi-ku, Kobe 673-02
Tel. 78-991-5614
Fax. 78-991-5605

Dear Dr. Chatt;

I am sending a new sample of diamond film coated on microchannels. The experimental conditions are as follows;

Method of deposition: microwave plasma CVD
Source gas: 3% methane, 2% water and hydrogen
Gas pressure: 300 Torr
Flow rate: 300 sccm
Substrate: 4 inch n-Si(111)
Substrate temperature: 820 C
Microwave power: 4 kW
Duration of CVD: 4 hours
Film thickness: about 6 microns

I assume that the quality of the diamond coating is better in this sample than in the one sent to you before. I look forward to having the data of SEM analysis based on this film. If the coating is made successfully in this sample. I will synthesize a film of 30-50 microns.

49 H151A Dr. R. H. Chatt
Director Asia/Pacific
TRW Space 8 Defense Sector August 16,
1988
One Space Park
Redondo Beach
CA 90278

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Dear Dr. Chatt;

According to the TRW Specification 1, two samples of diamond
films were synthesized under identical experimental conditions and attached herewith for your examination. The experimental conditions are as follows:

Method of deposition: microwave plasma CVD
Methane concentration: 0.5%
Gas pressure: 31.5 Torr
Flow rate: 100 sccm
Substrate: n-Si(111) 2 cm x 1 cm
Substrate temperature: 800 C
Duration of CVD: 7 hours
Film thickness: about 1.5 micron

I hope that these samples are sufficient for the preliminary
examinations, but if you need more diamond films synthesized under
same/different conditions, would you please let me know.

An EACVD reactor for thick diamond films has been completed,

and will be in routine operation within approximately a month. The large CVD reactor using microwave is now operated at a gas pressure of 400 Torr and a microwave power of 4 kW, and thick films will be synthesized also within about a month after the optimum operational conditions are found.

81 H175C
82 H175D
83 H175E
84 H175F
85 H175G
86 H175H
4 H001F
110 H188B In collaboration with Nippon Aluminum Manufacturing Yoichi Tomii (Metal Processing), a lecturer of Kyoto University's Faculty of Engineering, and Mutsuhiko Yoshioka, a gaduate student, have succeeded in synthesizing a diamond film from gas phase at a reltively high speed of 90-100 microns per hour using a DC plasma arc generating device. The record for forming diamond films by gas phase synthesis using DC as the excitation source is 900 micron-thick films per hour. However, this new work showed that diamonds can be synthesized even with a simple device that amounts to an improved plasma arc welder.

Tomii and co-workers used a gas mixture of hydrogen, methane and argon, and discharged from a nozzle a DC plasma generated under a pressure of 2.67 kilopascals, a discharge current of 40 amperes, and a discharge voltage of 35-400 volts. A diamond film was formed on a pure titanium substrate kept at 800- 1200 deg C by impinging the plasma on the substrate.

Depending on the gas ratio of hydrogen and methane or the plasma density, the precipitated diamond ranges from single crystal grains of about 0.1 um in diameter to micro-crystals of 1 micron or less in diameter or spherical crystals shaped like dumplings. However, it is difficult to form thin films because even the crystals precipitated as a film peel off eventually.

Tomii and coworkers will continue to study the detailed mechanism of diamond formation by DC plasma arc.

116 H192A PLASMA CVD IN LOW CRAVITY WITH A DROP CAPSULE

The influence of gravitational convection to the plasmawas shown by the arching of electric discharge. In the low gravity of 1.4 sec. by a drop cagsule, RF dischargeof Ar gas without arching between electrodes wasobserved. In the mixed gas of C2H5OH. H2. and/or Ar, thesame experiment carried out, and found the deposition of organic materials on the tip top of the electrodes. Bythe SEM and the TEM observation, dendrite or graphite, organic films with ripples of interesting shapes wereoften observed in the low garity experiment. Diamond was detected by electron diffraction analysis togetherwith the graphite and organic films.

A single type of drop capsule without drag-shield wasdeveloped for this experiment. The capsule was designedso slim that the

drag force of air was to be minimized.Low gravity of less than 4*10^-3G maximum at the bottom of drop tower of 14 m was obtained for 40 kg of weight.

This short time experiment with plasma in low gravity was suggesting the many interesting behaviors of plasma in space experiment in future.

6 H001H

76 H172A The growing of diamond thin film by the arc-discharge CVD method has been confirmed by X-ray diffraction. The growth speed was 200-250 pm/h. Raman spectroscopy conducted on the grown diamond thin film indicated that the film was of a good quality containing little non-diamond carbon such as graphite or amorphous carbon.

90 H178A Assoc. Prof. Yoichi Hirose of the Nippon Institute of Technology has succeeded in synthesizing diamond in the atmosphere for the first time in the world.

The epochal method employed by Hirose has been called the "open atmosphere combustion flame method". By this method, gas containing carbon, of which diamond is formed, is burnt and the inner flame (reducing flame) blasted onto a substrate under optimum conditions.

In conventional diamond synthesis techniques, a reaction chamber is used to apply high temperature and pressure while maintaining a vacuum condition to exclude the external atmosphere. Hirose's method is epochal in that it enables synthesis to be performed under normal atmospheric conditions. All that is required is a burner or a torch.

The principle of the method assures synthesis over a larger area, and also holds promise of both reducing the cost of diamond synthesis and of mass production. If the method is commerialized, it can be expected to have a profound impact on industrial materials.

Hirose reviewed the fundamentals of diamond synthesis methods published to date and noted that all CVD methods use plasma to decompose gases. He commenced a study of diamond synthesis by means of a flame, using plasma produced in the atmosphere for the combustion flame only. From these experiments he was able to confirm that when an inner flame of 1,500 C or hotter is blasted onto a tungsten carbide or silicon substrate heated to 600 C to 900 C, diamond particles or thin films are deposited on the substrate. Hirose succeeded in synthesizing diamond by using combustion flames combining propane with oxygen, acetylene with oxygen, methane with hydrogen, and alcohol with hydrogen.

The growth rate of diamond films is about 100um per hour. However, a maximum value of 200 um per hour can be attained for a particle form, and it is anticipated that this growth rate will be raised further in the near future. Free from the restrictions of a reaction chamber, this method facilitates the synthesis of diamonds. Hirose plans to synthesize diamond soon on a substrate 5 inches in diameter.

Conditions required for synthesis are not severe. Synthesis may thus be performed easily, and technology using a combustion flame holds great promise for future commercialization.

91 H178B SEE MEMO FIELD IN RECORD H178A

92 H178C SEE MEMO FIELD FOUND IN RECORD H178A

88 H177A Prof. Akio Hiraki

Faculty of Engineering
Osaka University

Diamond has strong resistance to heat and radioactive rays and, unlike silicon, can be used in extremely harsh environments. Many low pressure diamond synthesis techniques have been developed recently, making itpossible to form thin diamond film.
Prof. Hiraki has made a 3 X 3-cm, 10-um thick diamondfilm by turning a mixture of methane and hydrogen intoplasma at a temperature of 700"C and forming it into auniform diamond film by means of magnetic control usingelectronic cyclotron resonance. By using this method andincreasing the scale, a 10 X 10-cm film will becomepossible.
Now that it is possible to form a 3x3 cm, and soon a10x10-cm, diamond film, it has become possible to developharsh-enviroment-resistant LSi boards, and N-type andP-type semiconductors by doping the film with impuritiessuch as boron (B), aluminum (Al) and phosphor-ous (P).

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50 H144A Showa Denko K.K., a major integrated chemical company has developed a new type of technology for forming 100% polycrystalline diamond material. The company plans to make the diamond material as an ultra-high-functional material for machinery parts, medical instruments and optical equipment. Showa Denko's approach, based on the chemical vapor deposition (CVD) process, is to inject a reactor with methane or alcohol vapor diluted with hydrogen. High- frequency waves, microwaves and electron beams are then used to form the diamond material on a base material. Showa has succeeded in preventing any warping or formation of cracks or fissures when the diamonds are cooled from a temperature of 800 degreesC. The resulting diamond can be made to the required thickness, ranging from 2 to 100. microns, even on complex shaped base materials. The diamond material resists corrosion if used on a vacuum or in an inactive gaseous environment. Its thermal conductivity exceeds that of copper.

59 H064A TECHNOLOGICAL APPLICATION OF CVD DIAMOND

Various CVD methods of diamond synthesis have been developed succesfully over the past 10 years. But practical applications of CVD diamond are limited toonly a few, such as the speaker diaphragm, the X-ray

window etc.. As is well known, the charateristics ofdiamond, such as super hardness, high yongs modurus,optical tranceparency, low dielectric constant, chemical innertness etc, is useful to various fields. Recently,the possibility of a diamond semiconductor has beenrealized and the epitaxial growth of semiconductingdiamond has been studied. The quarity demanded from the CVD diamond is different in each fields appliction, so the process will be selected according to theappiication field.

Many of the anticipated fields of CVD diamond applicationwill be using daimond as a bulk material. For example, it is required to be at least 100um in thickness for useas a heat sink. In these cases, the deposition rate isvery important. But the quality or diamond becomes worsewith the deposition rate increases.

The development of CVD diamond application in Japan will be introduced and the future of CVD diamond will be discussed.

i

77 H173A Technology Developed To Make Large Diamonds

Sumitomo Electric Industries Ltd. has developed the technology to mass produce the largest single-crystal synthetic diamond. the

maker said July 31.

The diamonds are plate-shaped and have sides measuring 8-12mm in diameter, compared with 4mm for the existing largest synthetic diamond. The stones weigh 5-9 carats (1 carat = 0.2 grams).

The company plans to install the diamonds in its bonding tools, which are used to bond integrated curcuits on semiconductor boards, and on its heat sinks for semiconductor devices. The price for bonding tools with the 4sq.mm. with diamonds will be Y400,000-500,000 and those with 8sq.mm. diamonds will sell for Y1.5 million, according to the company.

87 H176A Single-Crystal Diamonds Produced For Industrial Use

Sumitmo Electric Industries Ltd. is mass-producing large single-crystal industrial diamonds. The diamonds weigh between five and nine carats and messure around 0.4 inch in diameter. The company first began to mass-produce 1.2-carat diamonds in 1985.

Sumitomo said that after its initial achievement with the smaller, single crystal diamond, growing demand for a larger synthetic diamond arose. Natural diamonds are too expensive for most industrial uses.

The increased size of the latest product offers new possible uses, the company said. The semiconductor industy has been particularly interested since the technology could help satisfy demand for a larger heat sink. Heat sinks are used to spread heat from the surface of a light-emitting semiconductor.

Diamonds, besides being the hardest substance onearth, have a highly efficient ratio of heat transmission and resist distortion from heat.

Company officials said the technology could also beused for bonding tools. Thin products, such as electic diariesand liquid crystal televisions, require thermostable partslike diamonds that can stand up to long use under harshconditions, they said.

Sumitomo said that in addition uses in bonding toolsand heat sinks, the diamonds could find medical applications.They migght be used in making ultra-hard scalpels.

108 H186A Mass Production Techniques for large syntnetic Diamond Monocrystals

Sumitomo Electric has established mass production techniques for large synthetic diamond monocrystals of 5 to 9 carats and a centimeter in diameter. On the basis of advanced control techniques which make possible the maintainance of fixed synthesis conditions, high temperatures and superhigh pressures for long periods of time, they succeeded, with excellent reproducibility, in synthesizing large diamond monocrystals with few impurities. In contrast to existing diamond products with edge lengths of 4 x 4 mm and heights of 1 mm, with this diamond they have been able to produce 8 x 8 mm edge lengths and heights of 3 mm. They have also achieved large reductions in costs, to approximately one-third the price of natural diamonds. Against a background of rapidly increasing demand for large sized diamond monocrystals for bonding seals and heat sinks, they expect yearly sales of Y200 million.

By expanding upon existing synthsis Sumitomo Electric has established mass production techniques which will make possible the steady synthesis of large synthetic

diamond monocrystals in the 1 centimeter class with quality as good as that of existing products.

The synthetic diamlond monocrystal is flat and square shaped and was produced at high temperature and super-high pressure of 50,000 to 60,000 atmospheres. They were able to strive for increased size in diamond mono-crystals by maintaining fixed pressures and temperatures for long periods of time extending to 200 hours.

Sumitomo Electric is the sole manufacturer of diamond monocrystals and because they have been able to supply products only up to the 4mm edge size, it has been difficult to bring bonding seals larger than this into practical use. By using the 1 centimeter class diamond here, products as large as 8 mm sizes will become possible.

In regard to heating uses, with improvements in performance in the latest semiconductor lasers, there has been a remarkable demand for large diamond heat sinks. By using these large diamonds, it will become possible to supply heat sinks with lengths as long as 12 mm, products which up to now could not be manufactured with edge lengths longer than 4 mm. They have also begun producing materials for diamond scalpels for surgery, infrared windows which include laser light, etc.

75 H171B The Itami Research Institute of Sumitomo Electric Industries, Ltd., was successful in test-producing luminescent devices using diamond thin films. The firm produced a diode (LED) type device which contained a B-doped, single-crystalline

diamond thin film formed over an artificial diamond substrate by the plasma CVD method. The film formation conditions included

a 200-SCCM hydrogen flow containing a 0.5-percent concentration

of CH4, a ratio of B to C at 100 ppm, and a pressure of 40 Torr.

The plasma frequency and the output were 2.40 GHz and 400 W, respectively. Placed over the diamond layer are a Schottky-junctioned W electrode and an ohmic-junctioned Ti electrode. Luminescence occurred around the Schottky electrode (W) when a dirrect current of several 10s to 100V was applied, and a spectral peak was found in the vicinity of 530nm. The luminance was not detennined.

104 H183A Diamond Synthesis Using Thermal Plasma

Using thermal plasmas to synthesize diamonds takes advantage of greatly enhanccd reaction rates by radicals, which are particularly abundant in thermal plasmas.

On the other hand, temperatures of 5 x 10^3 to 2 x 10^4K in thermal plasmas are too high for synthesizing diamonds, and a substrate must be thoroughly cooled.

Typical methods for generating thermal plasmas arc direct-current arc discharges between electrodes and high frequency (HF) induction discharges by induction heating of a gas. Both methods use Joule heating of agas. The former recquires electrodes while the latter doesnot.

COMPARISON OF PLASMA

	Direct current	High frequency
Device cost	Inexpensive	Expensive
Electric power efficiency	Good	Low
Plasma generation technique	Easy	Difficult
Plasma region	Narrow	Wide
Plasma stability	Good	Bad (needs improvement
Limitations on atmospheres that can be used	Yes	No
Plasma flow speed	Fast(hundreds of m/s)	Slow (tens of m/s)
Impurity mixing	Likely	Unlikely

Diamond synthesis by hot plasmas has just begun, and manyexperimental aspects are yet unclear. There are manyproblems to be solved, such as control of the substratetemperature, uniform film thickness, adherence of diamondfilms, diamond formation formation rate, and purity ofthe product. When these difficulties are overcome,applications of hot plasmas to coatings where largevolume processing is required or to synthesis of thickfilms will become popular. We also expect that thesynthesis of diamond powder using a gas phase method will be reported soon.

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57 H180A We have developed a new microwave plasma torch (MW plasma jet), which can generate a pure H2 plasma jet at atmospheric pressure from the end of a center electrode with an input power above 2 kW. The electric field has maximum strength at the end of the electrodes, so the plasma is initially ignited by the electric breakdown. The plasma jet seems to be powered and sustained by the electromagnetic field generated between the electrodes and/or in the chamber. Accordingly, the mechanism to sustain the plasma is considered to be different from that to initially ignite the plasma. In order to confirm the effectiveness of this plasma for CVD processes, the MW plasma jet has been applied to the synthesis of diamond from Ar-H2-CH4 system. Diamond particles or films were successfully synthesized at a higher rate (30um/h) on a larger area (25 X 25 mm^2) compared with the usual synthesis methods. The growth rate was in proportion to substrate temperature and/or CH4/H2 ratio up to 1200C and/or 10 vol %, respectively. These conditions little different from those of other methods reported so far. The results derived confirmed that the MW plasma jet has unique characteristics and that the process developed here was effective for the synthesis of diamond.

41 H165A Film With Semiconductive Properties (II)

It has already been reported that the doping of boron (B) on diamond could be accomplished by vaporizing an organic compound dissolved in boric acid and using this material as a reaction gas without applying a poisonous gas such as diborane. In this experiment, epitaxial growth on a single diamond crystalline base plate was attempted by applying this method. The electrical

and crystalline characteristics of the diamond thin film obtained

by this method are discussed. As an example, SEM photographs of the cross section and surface of the thin film synthesized in conditions where B/C = 10 ppm are shown in Figure 1 [not reproduced]. This thin film is relatively flat and is similar
to a non-doped diamond thin film. As shown in Figure 2 [not reproduced] the RHEED pattern of the thin film is a spot shape. This indicates that, the thin film has epitaxial growth in the direction of (110). In addition, as B/C increases, the resistance of the thin film obtained decreases, and deterioration

in the flatness of the crystalline surface is seen.

71 H071A Synthesis of Diamond Film by Arc Discharge Plasma CVD

Research on the gas-phase synthesis of diamond has progressed rapidly. Recently it is possible to deposit diamond by thermal filament CVD method, microwave plasma CVD method, RF plasma CVD method, DC plasma jet CVDmethod and so on, and various studies have been reported aboutgrowth rate of diamoad film and its crystallization.
In this study, synthesis of diamond film by arc discharge plasma CVD was being examined. First, newly designed deposition system was presented. This system generates a stablized, long plasma flame. Secondly, effects of deposition conditions of methane concentration and substrate temperature were discussed.

3. Experimental results and discussions

In order to obtain a homogeneous diamond film, it is necessary to stabizize the plasma flame and to keep substrate temperature constant. In this experiment, the deposition conditions of atmospheric pressure of 10-100 kPa, output power of 7.1kw and cH4 gas inlet position of 30-120 mm from N-nozzle are suitable for stabilizing the substrate temperature respectively.
Simultaneously, the deposition conditions of methane concentration, gas flow rate and substrate temperature have large effects on the diamond growth. We have done studies of the effects of those depositionconditions.The standard deposition conditions are shownin Table 1.
e

Table 1 Standard deposition conditions

Atmospheric pressure	23 kFa
Output Power	8 kW
Methane Injection position from N-Nozzle	90 mm
Methane concentration (CH4/H2 vol.%)	14 %
Methane Flow Rate	0.3 SLPM
Substrate	Silicon
Substrate temperature	1000 deg. C
Deposition time	30 min.

Substrate temperature was varied from 700Deg C to 13oo DEG C. At the lower temperature of 700oC, only amorphous carbon was deposited: and in case the temperature exceeded 1300C, both diamond and graphite were deposited. so, we consider thae the substrate temperature of s about 1000C is suitable.
We expect that this apparatus which S has high output power and stabilized plasma flame enables to deposit thick diamond plate with high growth rate.

73 H170A Ononda Cement plans to distribute whetting grain, thick film samples and to sell the same-type diamond production device. In addition they also are hoping to develop applications of the diamond for semiconductor radiation heat sinks, bites, precision polishing materials, in addition to the whetting grain.

72 H0000 LARGE SURFACE FILM DEPOSITION PROCESS

The RF Plasma injection chemical vapor deposition (PI-CVD) process can be used to deposit a very thin, low quality, fim

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN
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APPENDIX I

HIGH SPEED DATA PROCESSING (HSDP)

0102000000 - HSDP - SYSTEM PERFORMANCE

0201010A00 - SUPERCOMPUTERS

0204010A03 - MAGNETIC DISK MEMORY UNITS

0204010A04 - HIGH DENSITY MAGNETIC TAPE MEMORY UNITS

0204020A03 - WRITABLE OPTICAL DATA STORAGE DISK UNITS

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01020 00000	A	JA	D	P	I009A	P	Y	SEE MEMO
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02010 10A00	A	JA	A	P	I016D	P	N	HITACHI, LTD., COMPUTER DEVELOPMENT DEPT., KANAGAWA WORKS
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02010 10A00	A	JA	D	P	I006A	P	Y	NEC CORPORATION
02010 10A00	A	JA	C	P	I009D	P	N	NEC CORPORATION
02010 10A00	A	JA	E	S	I009E	I002A	N	NEC CORPORATION
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02010 10A00	A	JA	D	P	I008B	P	Y	NIPPON ELECTRIC COMPANY
02010 10A00	A	JA	D	P	I008C	P	Y	NIPPON ELECTRIC COMPANY
02010 10A00	A	JA	C	P	I008D	P	Y	NIPPON ELECTRIC COMPANY
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02040 10A03	A	JA	A	P	I006E	P	Y	NIPPON ELECTRIC COMPANY
02040 10A03	A	JA	C	P	I017A	P	Y	NIPPON TELEGRAPH & TELEPHONE, ELECTRICAL COMMUNICATIONS LABORATORIES

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02040 10A04	A	JA	B	P	I011A	P	N	SONY CORPORATION
02040 10A04	A	JA	B	P	I011B	P	N	SONY CORPORATION
02040 10A04	A	JA	B	P	I011C	P	N	SONY CORPORATION
** *** SUB-TECHNOLOGY: WRITABLE OPTICAL DATA STORAGE DISK UNITS								
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02040 20A03	A	JA	B	P	I018A	P	Y	NIPPON TELEGRAPH AND TELEPHONE, ELECTRICAL COMMUNICATIONS LABORATORY
02040 20A03	A	JA	B	P	I012A	P	N	SONY CORPORATION

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: HIGH SPEED DATA PROCESSING

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: HIGH SPEED DATA PROCESSING							
01020 00000 A HSDP	PROCESSING POWER --- GFLOPS (BIL. FL.PT.OPS./SEC) --- IMPR. DIR: H	(SEE OTHER CTLS) --- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF
** ******************** SUB-TECHNOLOGY: SUPERCOMPUTERS							
02010 10A00 A HSDP	PROCESSING POWER --- GFLOPS(BILL.FL.PT. OPS./SEC.) --- IMPR. DIR: H	I/O BANDWIDTH --- GBYTES/SEC (BILLION BYTES/SEC) --- IMPR. DIR: H	MEMORY SIZE --- GBYTES --- IMPR. DIR: H	CLOCK CYCLE --- ns (NANOSECONDS) --- IMPR. DIR: L	NUMBER OF PROCESSORS --- QTY --- IMPR. DIR: H	COMPILER --- TYPE --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: MAGNETIC DISK MEMORY UNITS							
02040 10A03 A HSDP	DATA TRANSFER RATE (PER DRIVE) --- MByte/sec (MILLION BYTES/SEC) --- IMPR. DIR: H	STORAGE CAPACITY (PER DRIVE) --- GByte (BILLION BYTES) --- IMPR. DIR: H	DIMENSIONS OF DRIVE (W x H x D) --- cm (CENTIMETERS) --- IMPR. DIR: L	RELIABILITY (MTBF) --- HOURS --- IMPR. DIR: H	TYPE OF DISK (RIGID or FLEXIBLE) --- NONE --- IMPR. DIR: X	--- --- IMPR. DIR:	COMP
** ******************** SUB-TECHNOLOGY: HIGH DENSITY MAGNETIC TAPE MEMORY UNITS							
02040 10A04 A HSDP	DATA TRANSFER RATE (PER CASSETTE) --- MByte/sec (MILLION BYTES/SEC) --- IMPR. DIR: H	STORAGE CAPACITY (PER CASSETTE) --- GBytes (BILLION BYTES) --- IMPR. DIR: H	CASSETTE SIZE (SMALL,MEDIUM,LARG E) --- NONE --- IMPR. DIR: X	BIT ERROR RATE --- 10^-10 --- IMPR. DIR: L	SYSTEM STORAGE CAPACITY (PER JUKEBOX) --- TBytes --- IMPR. DIR: H	JUKEBOX DIMENSIONS (W x H x D) --- METERS --- IMPR. DIR: L	COMP
** ******************** SUB-TECHNOLOGY: WRITABLE OPTICAL DATA STORAGE DISK UNITS							
02040 20A03 A HSDP	DATA TRANSFER RATE --- Kbytes/sec (KILOBYTES/SEC) --- IMPR. DIR: H	STORAGE CAPACITY (PER DISK) --- Gbytes (GIGABYTES) --- IMPR. DIR: H	DISK SIZE (DIAMETER) --- cm (CENTIMETERS) --- IMPR. DIR: L	BIT ERROR RATE --- 10^-12 --- IMPR. DIR: L	SYSTEM STORAGE CAPACITY (PER JUKEBOX) --- Gbytes (GIGABYTES) --- IMPR. DIR: H	JUKEBOX SIZE (W x H x D) --- METERS --- IMPR. DIR: L	COMP

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: HIGH SPEED DATA PROCESSING												
01020 00000 A HSDP 48	D	AGENCY OF INDUSTRIAL SCIENCE & TECHNOLOGY ---- 1-2, NAMIKI, TSUKUBA, IBARAKI PREF. 305, JAPAN ---- ---- LARGE-SCALE PROJECT -SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	10 ---- SEE MEMO	----	----	----	----	----	JAJ/01- 10-90/0 110 01/10/9 0 I019A / / JA
01020 00000 A HSDP 30	D	SEE MEMO ---- SEE MEMO ---- SEE MEMO ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P RD U	10 ----	----	----	----	----	----	JEO/11- 01-89/0 67 11/01/8 9 I009A 03/01/9 0 JA
** ############### SUB-TECHNOLOGY: SUPERCOMPUTERS												
02010 10A00 A HSDP 42	E	ELECTROTECHNICAL LABOTATORY ---- 1-1-4 UMEZONO, TSUKUBA-SHI, IBARAKI, 305, JAPAN ---- K.HIRAKI, S.SEKIGUCHI, T.SHIMADA ----	---- ---- ----	---- ---- ----	N A FP U	---- SIGMA- 1 DATA NOT REPORT ED	----	----	----	----	----	JEV/11- 14-88/0 374 11/14/8 8 I014A / / JA
02010 10A00 A HSDP 8	A	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P FP U	16 ---- VP-XXX	----	----	----	4 ----	----	JAA/VOL 4 #9/004 10/20/8 9 I002B 01/01/9 1 JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A HSDP 31	C	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	1.7 ---- MODEL FP400E	----	.25 ---- EXPAND ED MEMORY 1 GBYTE	7 ----	1 ----	----	JED/11- 01-89/0 65 11/01/8 9 I009B 11/01/8 9 JA
02010 10A00 A HSDP 11	D	FUJITSU LTD. ---- 6-1, MAROUNCHI, 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- VP-200	----	.256 ----	7.5 ----	----	VECTOR IZATIO N ----	JEH/12- 16-85/0 320 12/16/8 5 I003A / / JA
02010 10A00 A HSDP 16	A	FUJITSU LTD. ---- 6-1, MAROUNCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P FP U	4 ---- FUJITS U VP-260 0 PLANNE D FOR SUMMER OF 1989	----	----	----	----	----	JAO/VOL 4 #2/072 06/01/8 9 I004D 06/01/8 9 JA
02010 10A00 A HSDP 24	A	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P DT U	40 ----	----	----	----	8 ----	----	JAA/VOL 3 #12/002 11/30/8 8 I007A 10/01/8 9 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A HSDP 35	A	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P FP U	4 ---- MODEL VP2600	----	2 TO 8 ----	4 ----	2 ----	FORTRA N ----	JEO/11-01-89/0 66 11/01/8 9 I009F 06/01/9 0 JA
02010 10A00 A HSDP 44	D	HITACHI, LTD., COMPUTER DEVELOPMENT DEPT., KANAGAWA WORKS ---- 1 HORIYAMASHITA, HADANO, KANAGAWA 259-13, JAPAN ---- H.WADA, S.KAWABE & T.ODAKA ----	---- ---- ----	---- ---- ----	N A FP U	0.375 ---- MODEL-S-820/ 20	0.288 ----	0.128 ----	4 ----	----	AUTO VECTOR FORT77 /HAP ----	JEX/VOL 1/0139 / / I016A / / JA
02010 10A00 A HSDP 45	D	HITACHI, LTD., COMPUTER DEVELOPMENT DEPT., KANAGAWA WORKS ---- 1 HORIYAMASHITA, HADANO, KANAGAWA 259-13, JAPAN ---- H.WADA, S.KAWABE & T.ODAKA ----	---- ---- ----	---- ---- ----	N A FP U	0.75 ---- MODEL: S-820/ 40	0.288 ----	0.256 ----	----	1 ----	AUTO VECTOR FOR77/ HAP ----	JEX/VOL 1/0139 / / I016B / / JA
02010 10A00 A HSDP 46	C	HITACHI, LTD., COMPUTER DEVELOPMENT DEPT., KANAGAWA WORKS ---- 1 HORIYAMASHITA, HADANO, KANAGAWA 259-13, JAPAN ---- H.WADA, S.KAWABE & T.ODAKA ----	---- ---- ----	---- ---- ----	N A FP U	1.5 ---- MODEL: S-820/ 60	0.288 ----	0.256 ----	----	1 ----	AUTO VECTOR FORT77 /HAP ----	JEX/VOL 1/0139 / / I016C / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A HSDP 47	A	HITACHI, LTD., COMPUTER DEVELOPMENT DEPT., KANAGAWA WORKS ---- 1 HORIYAMASHITA, HADANO, KANAGAWA 259-13, JAPAN ---- H.WADA, S.KAWABE & T.ODAKA ----	---- ---- ----	---- ---- ----	N A FP U	3 ----	0.288 ----	.512 ----	4 ----	1 ----	AUTO VECTOR FORT77 /HAP ----	JEX/VOL . 1/0139 / / I016D / / JA
02010 10AC0 A HSDP 7	A	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A PP U	22 ---- SX-3	1 ----	2 ----	2.9 ----	4 ----	----	JAA/VOL 4 #9/004 10/20/8 9 I002A 01/01/9 0 JA
02010 10A00 A HSDP 23	D	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	.665 ---- NEC SX-1A	----	----	----	----	----	JAA/VOL 4 #3/002 03/31/8 9 I006A / / JA
02010 10A0C A HSDP 33	C	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	1.3 ---- MODEL SX-2	----	1 ---- EXTEND ED MEMORY 8 GBYTES	6 ----	1 ----	FORTRA N 77 ----	JEO/11- 01-89/0 65 11/01/8 9 I009D 05/01/8 5 JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A HSDP 25	D	NIPPON ELECTRIC COMPANY ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	.250 ---- MODEL SX-JA	----	----	----	----	----	JAA/VOL 3 #4/001 04/25/8 8 I008A 06/01/8 8 JA
02010 10A00 A HSDP 26	D	NIPPON ELECTRIC COMPANY ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	.330 ---- MODEL SX-1EA	----	----	----	----	----	JAA/VOL 3 #4/001 04/25/8 8 I008B 06/01/8 8 JA
02010 10A00 A HSDP 27	D	NIPPON ELECTRIC COMPANY ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	.665 ---- MODEL SX-1A	----	----	----	----	----	JAA/VOL 3 #4/001 04/25/8 8 I008C 06/01/8 8 JA
02010 10A00 A HSDP 28	C	NIPPON ELECTRIC COMPANY ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	1.3 ---- MODEL SX-2A	----	----	----	----	----	JAA/VOL 3 #4/001 04/25/8 8 I008D 06/01/8 8 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: MAGNETIC DISK MEMORY UNITS												
02040 10A03 A HSDP 29	A	NIPPON ELECTRIC COMPANY ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	20 ---- SEE MEMO	----	----	----	----	----	JAA/VOL 3 #4/001 04/25/8 8 I008E 06/01/8 8 JA
02040 10A03 A HSDP 49	C	NIPPON TELEGRAPH & TELEPHONE, ELECTRICAL COMMUNICATIONS LABORATORIES ---- MUSASHINO-SHI, TOKYO, JAPAN ---- Y.MITSUYA, S.TAKANAMI, Y.KOSHIMOTO ---- SEE MEMO	NIPPON TELEGRAPH & TELEPHONE, ELECTRICAL COMMUNICATIONS LABORATORY ---- MUSASHINO-SHI, TOKYO, JAPAN ---- I.SATO ----	---- ---- ----	Y A FP U	4.4 ----	8.8 ----	----	---- BETTER THAN 5 YEARS MAINTE NANCE FREE OPERAT ION	RIGID ----	----	JFB/05-11-87/0 118 05/11/8 7 I017A 06/01/8 7 JA
** *************** SUB-TECHNOLOGY: HIGH DENSITY MAGNETIC TAPE MEMORY UNITS												
02040 10A04 A HSDP 37	B	SONY CORPORATION ---- 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU, TOKYO 141, JAPAN ---- ---- RESEARCH PERFORMED BY TRW EXPERT ON SONY'S DATA RECORDER	---- ---- ----	---- ---- ----	N A FP U	032 ---- DATA RECORD ER	012 ----	SMALL ----	10^-10 ----	025 ----	3.35x2 .13x1. 22 ----	JEE/04-10-89/0 01 04/10/8 9 I011A / / JA
02040 10A04 A HSDP 38	B	SONY CORPORATION ---- 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU, TOKYO 141, JAPAN ---- ---- RESEARCH PERFORMED BY EXPERT ON DATA RECORDERS PRODUCED	---- ---- ----	---- ---- ----	N A FP U	032 ---- DATA RECORD ER	40 ----	MEDIUM ----	10^-10 ----	025 ----	3.35x2 .13x1. 22 ----	JEE/04-10-89/0 01 04/10/8 9 I011B / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02040 10A04 A HSDP 39	B	SONY CORPORATION ---- 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU, TOKYO 141, JAPAN ---- ---- RESEARCH OF SONY CORPORATION DATA RECORDER PROVIDED BY TRW EXPERT	---- ---- ----	---- ---- ----	N U FP U	032 ---- DATA RECORD ER	090 ----	LARGE ----	10^-10 ----	025 ----	3.35x2 .13x1. 22 ----	JEE/04- 10-89 04/10/8 9 I011C / / JA

** ############### SUB-TECHNOLOGY: WRITABLE OPTICAL DATA STORAGE DISK UNITS

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02040 20A03 A HSDP 43	A	FUJITSU, LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- YUGI INOUYE ----	NATIONAL AEROSPACE LABORATORIES (NAL) ---- TOKYO, JAPAN ---- SHIGEKI HATAYAMA ----	---- ---- ----	N A FP U	326 ---- FACOM 6443	8.89 ----	----	1 ----	----	----	JEV/11- 14-88/0 266 11/14/8 8 I015A / / JA
02040 20A03 A HSDP 50	B	NIPPON TELEGRAPH AND TELEPHONE, ELECTRICAL COMMUNICATIONS LABORATORY ---- MUSASHINO-SHI, TOKYO, JAPAN ---- K.ITAO, A.YAMAJI, S.HARA & N.IZAWA ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	920 ---- 0.92 MS/sec	0.54 ---- .54MB	13 ----	1 ----	13 ----	.7x.43 x.6 ---- 700mmX 430mmX 600mm	JFB/05- 11-87/0 92 05/11/8 7 I018A / / JA
02040 20A03 A HSDP 40	B	SONY CORPORATION ---- 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU, TOKYO 141, JAPAN ---- ---- RESEARCH DATA PRVIDED BY EXPERT	---- ---- ----	---- ---- ----	N A FP U	0300 ----	03.2 ----	030.48 ----	10^-12 ----	0164 ----	.91x2. 13x1.5 2 ----	JEE/S.H SU / / I012A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: SUPERCOMPUTERS												
02010 10A00 A 1009F HSDP 9	A	FUJISU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P FP U	4 ---- VP-260 0	----	----	----	1 ----	----	JAA/VOL 4 #9/004 10/20/8 9 I002C 01/01/9 0 JA
02010 10A00 A 1009F HSDP 6	A	FUJITSU CORPORATION ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A PP U	4 ---- VP2600	----	2 ---- EXPAND ABLE TO 8	----	1 ----	----	JAA/VOL 4 #4/002 03/31/9 9 I001A 01/01/9 0 JA
02010 10A00 A 1009F HSDP 20	A	FUJITSU LTD ---- 6-1, MARONUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P FP U	4 ---- FUJITS U VP-260 0	----	----	----	1 ----	----	JAJ/09- 29-89/0 17 09/29/8 9 I005C 04/01/9 0 JA
02010 10A00 A I009B HSDP 13	C	FUJITSU LTD. ---- 6-1, MAROUNCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	1.7 ---- FUJITS U VP-400 E	----	1 ----	7 ----	----	----	JAO/VOL 14 #2/073 06/01/8 9 I004A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	MEST PHSE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A 1002B HSDP 21	A	FUJITSU LTD. ---- 6-1, MARONUNCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P FP U	16 ---- FUJITSU VP-XXX NSS ESTIMATE	----	----	----	4 ----	----	JAJ/09- 29-89/0 17 09/29/8 9 1005D 01/01/9 1 JA
02010 10A00 A 1009F HSDP 36	A	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A DT U	04 ---- MODEL VP2600 /10 & 20	----	2 ----	----	----	----	JER/12/ 07/88 12/07/8 8 1010A 12/06/8 8 JA
02010 10A00 A 1016D HSDP 10	A	HITACHI LTD ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	3 ---- S-820/ 80	----	----	----	1 ----	----	JAA/VOL 4 #9/004 10/20/8 9 1002D 01/01/8 8 JA
02010 10A00 A 1016A HSDP 12	D	HITACHI LTD. ---- 6, KANDA-SURUGADAI, 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	----	----	.256 ----	14 ----	----	VECTORIZATION ----	JEH/12- 16-85/0 321 12/16/8 9 1003B / / JA
02010 10A00 A 1016D HSDP 14	A	HITACHI LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	3 ---- HITACHI S-820/ 80	----	.512 ----	4 ----	----	----	JAO/VOL 4 #2/073 06/01/8 9 1004B / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A 1016D HSDP 22	A	HITACHI LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	3.0 ---- HITACH I S-820/ 80	----	----	----	1 ----	----	JAJ/09-29-89/0 17 09/29/8 9 I005E 01/01/8 8 JA
02010 10A00 A 1016D HSDP 32	A	HITACHI LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	3 ---- MODEL S-820-80	----	.5 ---- EXTEND ED MEMORY 12	4 ----	1 ----	----	JEO/11-01-89/0 65 11/01/8 9 I009C 05/01/8 5 JA
03010 10A00 A 1016D HSDP 41	A	HITACHI, LTD ---- 6-KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ---- BUILDER OF THE S-820/80 SUPERCOMPUTER	INSTITUTE FOR SUPERCOMPUTING RESEARCH ---- 8F RECRUIT KACHIDOKI BLDG, 2-11 KACHIDOKI, CHUO-KU, TOKYO, JAPAN ---- C.EOYANG & R. MENDEZ ---- PEOPLE DOING THE REPORTING OF THIS ARTICLE	---- ---- ----	Y A FP U	3 ---- S-820/ 80 SUPERC OMPUTE R	0.288 ----	0.512 ----	4 ----	1 ----	FOTRAN 77 ----	JEV/11-14-88/0 296 11/14/8 8 I013A / / JA
02010 10A00 A 1009D HSDP 15	C	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	1.3 ---- NEC SX-2A	----	1 ----	6 ----	----	----	JAO/VOL 4 #2/073 06/01/8 9 I004C / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: HIGH SPEED DATA PROCESSING

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02010 10A00 A 1002A HSDP 17	A	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P FP U	22 ---- NEC SX-3 DUE SPRING OF 1990	----	----	----	4 ----	----	JAO/VOL 4 #2/072 06/01/8 9 1004E 04/01/9 0 JA
02010 10A00 A 1002A HSDP 18	A	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- PLANNED DELIVERY DATE JUNE 1990	---- ---- ----	---- ---- ----	N P FP U	22 ---- NEC SX-3	1 ----	1-2 ----	2.9 ----	4 ----	----	JAJ/09- 29-89/0 17 09/29/8 9 1005A 06/01/9 0 JA
02010 10A00 A 1009D HSDP 19	C	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	1.3 ---- NEC SX-2 ANNOUN CED IN 1983	----	----	5.8 ----	----	----	JAJ/09- 29-89/0 18 09/29/8 9 1005B / / JA
02010 10A00 A 1002A HSDP 34	E	NEC CORPORATION ---- 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ----	---- ---- ----	---- ---- ----	N P FP U	22 ---- MODEL - NEC SX-X/S X-3/44	----	1 TO 16 ----	2.9 ----	4 ----	FORTRA N 77/SX C ----	JEO/11- 01-89/0 66 11/01/8 9 1009E 12/01/8 9 JA

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HIGH SPEED DATA PROCESSING

High speed data processing involves the converting of raw data to machine readable form and its subsequent rapid processing, which may include storing, updating, combining, rearranging, and outputting. High speed data processing (HSDP) equipment can vary in size and scope from the tiny microcomputer in a smart weapon (such as an IR heat-seeking missile) that evaluates data from a thermal sensor and continually issues steering commands to achieve an intercept, to the massive groundbased supercomputers that may identify and designate targets and invoke appropriate defensive weapons in a national space defense system.

While the microprocessors in weapons and the flight computers in missiles, aircraft and spacecraft all incoporate critical technology that is rapidly evolving in Japan and elsewhere, this technology category, termed "high speed data processing" has been focused to include only those systems or applications that involve enormous quantities of data and utilize a supercomputer. The status of microprocessor and flight computers will be measured best by the evaluation of another critial technology, VHSIC (very high speed integrated circuits) which are their basic building blocks.

Because computer technology is very dynamic, a supercomputer can only be defined in comparative terms, eg. "the most powerful computer available today". Computer performance, which is often measured in millions of floating point operations per second (MFLOPS), ranged from 50 to 500 MFLOPS in 1980 and will be in the range of 500 to 10,000 MFLOPS in 1990. Many components are even rated in GFLOPS (gigaflops) which are billions of floating point operations per second.

A high speed data processing system must then consist of a supercomputer, mass storage devices, networks and workstations. The supercomputers perform the number crunching tasks, while the workstations accept the users inputs and present the results to the user visually. The mass storage devices store the bulk data and the networks connect all the elements together. While the workstations and networks are essential elements of a data processing system, they are not presently considered either a critical or rapidly advancing technology that warrants being evaluated as a critical component.

Typical applications of high speed data processing include:

- Air traffic control
- Cryptographic analysis
- Military command & control
- High resolution reconnaissance image processing
- Computer and chip (microcircuit) design
- Chemical research
  - Molecular dynamics & molecular orbit theory
  - New catalyst development
  - Composite material design & performance models
- Engineering design and performance analysis
  - Aerodynamics
  - Structural analysis
  - Rocket engine design & performance
  - Automotive design & performance analysis
  - Production tooling design
- Economics

- Economic modelling
- Market analyses
- Investment analises

Scientific

- Quantum chromodynamics
- Molecular biology
- Theoretical and experimental physics
- Astronomical analyses - galactic dynamics
- Medical research - virus simulations
- Radio astronomy
- Weather forecasting
- Geological studies - earthquakes
- Oil exploration
- Oceanography

49 I019A LARGE-SCALE PROJECT BY AGENCY OF INDUSTRIAL SCIENCE &TECHNOLOGY

A high-speed computing system is clearly needed for suchoperations as the processing of satellite data,meteorlogical forecasting, aerodynamic simulation foraircraft design, and plasma simulation for nuclear fusionreactors. These operations require large-scale numericalcomputation in which the efficient calculation of vectorsand matrices is especially necessary.

this project is aimed at the development of a high-speedcomputing system for scientific and technologicalapplications. The system is expected to operated at therate of more than 10GFLOPS, which is 100 to 1000 timesfaster than the speed of conventional computers. In orderto develop high-speed computing system, two major R&Dprojects are being conducted: one on high-speed noveldevices such as Josephson junction device; the other oncomputer archiyecture, algorithms and languages forparallel computing. The target of this project is tofabricate and evaluate high performance demcnstrationsystem in 1989.

30 I009A NATIONAL SUPERCOMPUTER EFFORT

NAME	HIGH SPEED COMPUTING
PERIOD	JAN. 1982 - MAR. 1990
FUNDING	$140M (YEN 23B)
PERFORMANCE GOALS	10 GFLOPS
CURRENT OBJECTIVES	NEW DEVICES (JJ, HEMT) DEDICATED IMAGE PROCESSING SYSTEM PARALLEL ARCHITECTURE PARALLEL ALGORITHMS PARALLEL LANGUAGES
PARTICIPANTS	ELECTROTECHNICAL LABORATORY HITACHI FUJITSU NEC
METHODS FOR PUTTING RESULTS	INCORPORATED INTO INDUSTRIAL PARTICIPANTS OWN SUPERCOMPUTERINTO PRACTICE EFFORTS; SPECIAL-PURPOSE ARCHITECTURE FOR A NATIONAL NEED

2 10000

Supercomputers are defined as the fastest, most powerful (usually general-purpose) computers available at any given time. While the design philosophy of previous and current supercomputers has emphasized the extremely rapid processing of vectors (a particular type of calculation) newer systems based upon new technologies such as multiple processors are expected to supplant them.

The basic measure of performance is the rate at which it carries out floating point operations, which are essential for accurate high-speed matematical calculations. The criteria is stated in gigaflops (GFLOPS) which is a billion such operations per second. Because processing capability is so high, extremely efficient, high capacity, input/output subsystems are needed as well as exceptionally large, rapidly accessible active memory.

A number of approaches to improved perfomance are being investigated. Gallium arsenide chips are being developed to replace the current silicon ones, to provide smaller, higher speed circuits with better low-temperature operation. Another apporach uses multiple parallel processors, and yet another uses a liquid nitrogen immersion cooling system for ultra high speed chips. The use of optical fibers in place of electrical wire to transmit optical rather than electronic signals is also being considered. Optical storage techniques identical to that used on compact disks for high-fidelity music recording also has potential for superconputer data storage.

When Cray Research introduced the CRAY X-MP in 1982 it was the first supercomputer oferring multiprocessing. It has been supplied in two versions and eleven different options. Ten of these options operate at a clock speed of 8.5 nanoseconds. Single-processor models are available with memories of 4, 8 or 16 million words. Double-processor options include memories of 2, 4, 8,and 16 million words. Four-processor X/MP systems can be ordered with 4, 8, or 16 million word memories. Prices range from $5 million to 16 million. Multiple processor options of the X-MP are capable of dividing a program to be executed in parallel. The CRAY-2 introduced in 1985 has a 4.2 nanosecond clock time, a maximum of 256 million word common memory serving two or four processors, and imersion cooling, and its footprint occupied only 16 square feet.

ETA Systems, which is an outgrowth of Control Data Corporation, introduced the ETA-10 in 1986. It is a multiprocessor machine available with up to eight central processing units, each of which has scalar and vector capabilities and local memory of four million 64-bit words. The CPUs access a shared memory with options from 32 million to 256 million words. The ETA-10 is a virtual memory computer. While it operates without harm at room temperature, to achieve maximum performance from the CMOS chips it contains immersion cooling to temperatures of 175 degrees below zero C.

The CYBER 205 made by CDC are supplied with either two or four vector pipelines and memory sizes of 1, 2, 8, and 16 million 64-bit words, and a clock speed of 20 nanoseconds.

The IBM 3090 achieves supercomputer performance by adding vector processors to a basic mainframe design. It is available with 1, 2, 4, or 6 processors, and has a cycle time of 18.5 nanoseconds. It uses chilled water cooling, while the others all use liquid nitrogen. It is supplied with a shared memory of up to 640 million bytes.

42 I014A
9 I002C NEC has completed development of the SX-3 supercomputer, successor to its SX-2 series. The SX-3 series is reported to include seven models: multiprocessor models 22, 24, 42, and 44, and single processor models 11, 12, and 14. NEC is the first Japanese company to adopt the multiple-processor approach to supercomputing, departing from the tradition of designing supercomputers around one super central processing unit (CPU). Its multiprocessor SX-3 models are rated at 5.5 to 22 billion floating point operations per second (gigaflops or GFLOPS), and the single-processor models at 1.35 to 5.5 GFLOPS.

The world's fastest computer at present, rated at 10 GFLOPS, is a machine made by ETA Systems, a subsidiary of Control Data Corporation. Market leader Cray Research's fastest machine, the Y-MP, is rated at 4 GFLOPS, and the forthcoming Cray-3 is expected to be rated at 16 GFLOPS. A future Fujitsu supercomputer, yet to be offcially announced, is claimed to have a capability of 16 GFlOPS.

The SX-3 CPU has a clock cycle time of 2.9 nanoseconds (ns), half that of the CPU used in the SX-2. Its large-scale-integration (LSI) chips use low-energy current mode logic (LCML), integrating 20,000 gates and 485 input/output (I/O) pins. Gate delay time is 70 picoseconds (ps). The chips are mounted in 18.5-millimeter square ceramic flip TAB carriers (FTCs), with 604 I/O pads at a 0.675-millimeter pitch. The cache memory is random access memory (RAM) with an access time of 1.6 nanoseconds. The RAM chips are housed in 18.5-millimeter-square FTC's, with 588 I/O pads at a 0.675-millimeter pitch.

The CPU composses a 225- x 225- x 5.5-millimeter ceramic board permitting 8 wiring layers and a packaging density of up to 100 chips and 3,950 gates per square centimeter. Each chip has a power consumption of 33 or 38 watts, resulting in 50 to 55 deg C temperatures at its positive/negative (p/n) junctions. The chips are cooled by rapidly circulating water using a special method which is three times as efficient as that used for the SX-2 and which reduces the thermal resistance to 0.6 deg C per watt.

The SX-3 models have either one or two control processors with 64 to 256 megabytes of memory. There are 128 64-bit scalar registers. Up to four I/O processing units have a peak transfer rate of 1 gigabyte per second and a maximum of 256 channels. Expanded memory may range from 1 to 16 Gbytes and has a peak transfer rate of 2.75 Gbytes per second.

NEC has begun taking orders for SX-3 models, with domestic shipments scheduled to start by June 1990 and foreign shipments by the end of September 1990. The company's goal is to sell 120 units within the next four years, 30 percent overseas with half of these going to US customers. HNSX Supercomputer, a joint venture with Honeywell formed in 1986, will market the SX-3 in North America.

Despite claims of having the fastest machines in the world, Japanese supercomputer makers have not sold many in the United States. As of May 1989, Fujitsu had reportedly sold only two, NEC had leased one, and Hitachi had not installed any. The Japanese machines have tended to be more expensive than comparible US models, and there is relatively little software available for them. (There are more than 500 software packages for Cray machines but only 180 for NEC products.) The SX-3, too, suffers the disadvantage of a relatively small number of available software packages. NEC is attempting to overcome this disadvantage, in past, by offering the Super-Unix operating system based on Unix System V, release 3.1 .

Many in Japan believe NEC's advances in supercomputers will cause increased US concern over trade imbalance. To alleviate US/Japanese trade sanction over super-computers, NEC has decided to use mostly US chips in the SX-3 and has begun negotiations with US firms including Texas Instruments. About 65 percent of CPU logic and 100 percent of both main (256K static RAM) and expanded (1-megabit dynamic RAM) memory across the SX-3 series is expected to be US-made. At least 90% of the chips in the SX-3 model 14 will be of US origin.

6 I001A Fujitsu has developed a new FACOM VP2000 series ofsupercomputers. Each of the eight models in the seriescontains a single vector processor whose speed rangesfrom 0.5 gigaflops (billion floating point operations persecond) (VP2100) to 4 gigaflops (VP2600). New dual scalar processors have a total speed three times that of theprocessor in Fuitsu's M-780. Utilizing a 61-layer glassceramic board, the VP2000 supercomputers contain15,000-gate emitter-coupled logic chips with an80-picosecond delay. The 2-gigabyte memory, expandable to 8 gigabytes, consists of 1-megabit static randomaccess memory chips. There is also a combined RAM/logic cache with a 1.6-nanosecond access time. The computers support both the UTS-M (Fujitsu's own version of UNIX) and MSP operating systems. Shipment are scheduled to begin in 1990.

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20 I005C
31 I009B
11 I003A Fujitsu VP-200

The Fujitsu supercomputer has separate scalar and

vector units that can execute computations concurrently. The scalar unit, however, issues the instructions for the vector unit. The scalar unit was taken from their M380/382 series mainframes and runs a complete IBM S/370 instruction set. The cycle time of the scalar unit is 15ns (compared to the X-MP's 9.5ns), but a sampling of scalar instructions indicates that these operations may nominally be slightly faster than the X-MP's. There is, however, a difference in the pipelining between the X-MP and VP-200. Each VP-200 scalar instruction is pipelined in three stages-fetch, decode, and execute. The execution stage is not segmented, whereas the X-MP's is. Thus, there may less operation overlap in the VP-200 than in the X-MP.

The vector unit consists of two identical sets of functional units (multiply, divide, add, logical) operating on a 7.5-ns clock period. The total vector register capacity is 8K 64-bit words and can be reconfigured dynamically to a number of different combinations with varying vector register lengths. For example, 8 registers of length 1024 is a possible configuration, as well as 256 registers of 32 elements.

There are two paths from registers to memory that can be used for either loads or stores. Interestingly, the bandwidth of each pipe is 2 words (64 bits) every vector clock period or 1 word each half clock (3.75ns).

Fujitsu has designed three types of operations into th VP -200 to handle Fortran IF statements. The first type is the mask operation. The mask controls all functional units and prevents computations corresponding to a zero mask bit. There is no performance advantage to this type of mask control over the X-XMP's, but it does prevent overflow caused by zero divides. The second type of operation is a list directed random load and store where the memory addresses are computed from a vector of indices (e.g., R(J(I))), and the third type is a set of compress/expand instructions in which mask is used to load/store only those vector elements for which the IF statment is true.

The main memory capacity of the machine is 256 mega-bytes interleaved up to 256 ways. The VP-200 configuration that we used, however, had 64 million bytes of main memory interleaved 128 ways. There is also a 64-kilobyte cache between the scalar processor and main memory.

It should be noted that like the X-MP, memory conflicts can come from two different sources: a bank conflict from competing requests to the same bank or a section (Cray terminology) conflict from a request to the same memory port connecting memory with CPU (there are 8 such ports in the VP-200). For random accesses, the section conflict is more probable and is reported to result in a delay of one clock period.

In summary, the VP-200 appears to be a well designed machine based on Fujitsu's experience with their M380 series, currently among the fastest IBM compatible mainframes.

13 I994A
16 I004D
21 I005D

24 I007A (Japan) Fujitsu plans to announce a 40-GFLOPSsupercomputer with 20 times the speed of its VP-400supercomputer. Benchmark testing with actual data couldbegin by fall of next year. The new product willincorporate eight processors, each with a 5-GFLOPSspeed, in a 40-GFLOPS parallel processing unit usingHigh-Level Parallel Descriptive Language.

35 I009F

36 I010A

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12 1003B Hitachi S810/20

Hitachi's approach has been to employ independent scalar and vector processors. The S810/20 relies on their current top-of-the-line mainframe (the M280H) for their scalar processor with a cycle time or 28 ns. The vector unit was designed with a cycle time of 14ns. The model 20 has the most functional units of the three machines considered in this benchmark: four floating point add/logical units and eight combination multiply/divide-add units. In addition, there are six load and two store pipes to memory, each capable of loads/stores at a rate of one word (64 bits) per cycle.

The main memory capacity of the S810/20 is 256 megabytes (interleaved 128 ways) and, in addition, the Hitachi has a secondary memory much like the Cray X-MP's SSD with a capacity or 1024 megabytes.

The vector register capacity is 32 registers with a fixed length or 256 elements (64 bits) each. A unique feature of the Hitachi design is that vectors greater than 256 elements by strip-mine logic resident in hardware. Strip-mining becomes necessary for DO loops whose iteration count exceeds the maximum vector register length. In the Hitachi, for example, a loop of 512 iterations will be processed (stripmined) in 2 strips of vector length 256. All other machines in this class handle strip-mining in software.

Conditional branches are handled by mask operations or by list-directed loads/stores. Additionally, the Hitachi machine has hardware that enables loops with recursion to vectorize.

14 I004B
22 I005E
30 I009C
41 I013A A performance evaluation and comparison of the newHitachi S-820/80 supercomputer on a set of standardFortran benchmark codes which range from simple kernalsto fluid dynamic applications.
44 I016A
45 I016B
46 I016C
47 I016D
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The SX-3 CPU has a clock cycle time of 2.9 nanoseconds (ns), half that of the CPU used in the SX-2. Its large-scale-integration (LSI) chips use low-energy current mode logic (LCML), integrating 20,000 gates and 485 input/output (I/O) pins. Gate delay time is 70 pico-seconds (ps). The chips are mounted in 18.5-millimeter square ceramic flip TAB carriers (FTCs), with 604 I/O pads at a 0.675-millimeter pitch. The cache memory is random access memory (RAM) with an access time of 1.6 nanoseconds. The RAM chips are housed in 18.5-millimeter-square FTC's, with 588 I/O pads at a 0.675-millimeter pitch.

The CPU composses a 225- x 225- x 5.5-millimeter ceramic board permitting 8 wiring layers and a packaging density of up to 100 chips and 3,950 gates per square centimeter. Each chip has a power consumption of 33 or 38 watts, resulting in 50 to 55 deg C temperatures at its positive/negative (p/n) junctions. The chips are cooled by rapidly circulating water using a special method which is three times as efficient as that used for the SX-2 and which reduces the thermal resistance to 0.6 deg C per watt.

The SX-3 models have either one or two control processors with 64 to 256 megabytes of memory. There are 128 64-bit scalar registers. Up to four I/O processing units have a peak transfer rate of 1 gigabyte per second and a maximum of 256 channels. Expanded memory may range from 1 to 16 Gbytes and has a peak transfer rate of 2.75 Gbytes per second.

NEC has begun taking orders for SX-3 models, with domestic shipments scheduled to start by June 1990 and foreign shipments by the end of September 1990. The company's goal is to sell 120 units within the next four years, 30 percent overseas with half of these going to US customers. HNSX Supercomputer, a joint venture with Honeywell formed in 1986, will market the SX-3 in North America.

Despite claims of having the fastest machines in the world, Japanese supercomputer makers have not sold many in the United States. As of May 1989, Fujitsu had reportedly sold only two, NEC had leased one, and Hitachi had not installed any. The Japanese machines have tended to be more expensive than comparible US models, and there is relatively little software available for them. (There are more than 500 software packages for Cray machines but only 180 for NEC products.) The SX-3, too, suffers the disadvantage of a relatively small number of available software packages. NEC is attempting to overcome this disadvantage, in past, by offering the Super-Unix operating system based on Unix System V, release 3.1 .

Many in Japan believe NEC's advances in supercomputers will cause increased US concern over trade imbalance. To alleviate US/Japanese trade sanction over supercomputers, NEC has decided to use mostly US chips in the SX-3 and has begun negotiations with US firms including Texas Instruments. About 65 percent of CPU logic and 100 percent of both main (256K static RAM) and expanded (1-megabit dynamic RAM) memory across the SX-3 series is expected to be US-made. At least 90% of the chips in the SX-3 model 14 will be of US origin.

15 I004C

17 I004E

18 I005A

19 I005B

23 I006A (Japan) NEC will install one of its SX-1A supercomputersin the Singapore government's Computer Engineering Centerby year's end. This sale is the first of a Japanese-madesupercomputer to another Asian county. The machine, witha speed of 665 million floating-point operations persecond, will be used internally for research anddevelopment and will also serve remote users.

33 I009D

34 I009E

25 I008A (Japan) Nippon Electric Company has announced a new SX-A series of four supecomputers with a 40-percent price-performance improvement over its current models. Running on a version of UNIX and using disk drives with a 20-megabyte-per-second transfer speed, the SX-JA (250 MFLOPS) rents for 28 million yen per month, the SX-1EA (330 MFLOPS) for 37 million yen, the SX-1A (665 MFLOPS) for 51 million yen, and the SX-2A (1,300 MFLOPS) for 64 million yen. Shipments are planned for June.

26 I008B (Japan) Nippon Electric Company has announced a new SX-A series of four supecomputers with a 40-percent price-performance improvement over its current models. Running on a version of UNIX and using disk drives with a 20-megabyte-per-second transfer speed, the SX-JA (250 MFLOPS) rents for 28 million yen per month, the SX-1EA (330 MFLOPS) for 37 million yen, the SX-1A (665 MFLOPS) for 51 million yen, and the SX-2A (1,300 MFLOPS) for 64 million yen. Shipments are planned for June.

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28 I008D (Japan) Nippon Electric Company has announced a new SX-A series of four supecomputers with a 40-percent price-performance improvement over its current models. Running on a version of UNIX and using disk drives with a 20-megabyte-per-second transfer speed, the SX-JA (250 MFLOPS) rents for 28 million yen per month, the SX-1EA (330 MFLOPS) for 37 million yen, the SX-1A (665 MFLOPS) for 51 million yen, and the SX-2A (1,300 MFLOPS) for 64 million yen. Shipments are planned for June.

3 I0000

MAGNETIC DISK MEMORY UNITS

In its simplest form a magnetic disk is coated with minute iron oxide particles that respond to a magnetic field. The disk is installed in a disk drive that can accurately spin the disk, and contains one or more read/write heads that can generate a magnetic field and thus arrange the iron particles in patterns that correspond to the digital data being stored. The read head can then read this data on command. Typically, both sides of the disk are coated and is arranged in a large number of concentric tracks, which are subdivided into wedge shaped sectors. Computer generated data is stored on and retrieved from these tracks and sectors.

The familiar "floppy" disk used in personal computers is a small, inexpensive version of a flexible magnetic disk. The "hard disk" also contained in many PCs is a small inexpensive version of rigid magnetic data storage disk. Floppy disks are, of course, removable from the disk drive and are stored separately, while a hard disk may be either removable or permanently mounted with its drive assembly. In either case, rigid disks are produced as either single disks or in fixed stacks of two or more disks that are spaced far enough apart to allow for access of the read/write heads to both sides of each disk.

Both the rigid and flexible forms permit rapid random access to any data stored on them. The disk drive is spun to the sector containing the desired data and the read/write head is positioned on the desired track.

The capacities of both flexible and rigid magnetic disks continue to improve as the technologies of the recording surface, the read/write heads and the drive mechanism advance.

The design of sealed storage modules, for rigid disks, with their internal filtering devices have virtually eliminated dust particles, with a resultant increase in reliability. This cleaner environment, and the replacement of ferrite magnetic head technology with thin film heads of special aerodynamic design, has allowed heads to be spaced much closer to the surface (on the order of 20 micro-inches) allowing a much higher density of recording and a reduction in track width. A linear recording density of about 15,000 bits per inch has been achieved, yielding an area density of approximately 11 million bits per square inch.

A large capacity disk drive currently available combines two sealed head/disk assemblies of 1.26 gigabytes each, for a total of 2.52 gigabytes per drive, and it has a data transfer rate of three megabytes per second. Using two sets of actuators in each head/disk assembly cuts the average seek time to 16 milliseconds.

Thin film heads and thin film media provided densities of about 25,000 bits per inch and 2,000 tracks per inch in production-run high end fixed disks in 1987. The resulting density of 50 million bits per square inch could rise to 180 million bits per square inch in 1992, by a combination of thin film heads, thin film media, and vertical recording.

In vertical recording, the magnetized domains are stacked perpendicular to the surface of the substrate (rather than horizontally, as is the case in the present mode). Vertical recording at 100,000 bits per inch density has already been demonstrated in the laboratory and ultimate linear densities of 400,000 bits per inch are considered possible and could lead to densities of 400 million bits per square inch in 1997.

Moving head disk storage systems will continue to offer a significant cost advantage over other storage technologies throughout the 1982-1997 time period. However, this cost advantage will often be partly offset by the use of the buffered approach to reduce effective access time. Storage densities could increase more than tenfold to provide capacities in the tens of gigabytes per drive.

29 I008E (Japan) Nippon Electric Company has announced a new SX-A series of four supecomputers with a 40-percent price-performance improvement over its current models. Running on a version of UNIX and using disk drives with a 20-megabyte-per-second transfer speed, the SX-JA (250 MFLOPS) rents for 28 million yen per month, the SX-1EA (330 MFLOPS) for 37 million yen, the SX-1A (665 MFLOPS) for 51 million yen, and the SX-2A (1,300 MFLOPS) for 64 million yen. Shipments are planned for June.

49 I017A A large capacity, fast-access performance magnetic diskstorage system has been developed. The disk storagesystem, nicknamed "GEMMY", features a large-capaccity of8.8 GBytes per unit, fast average seek time of 12ms andhigh data rate of 4.4MByte/s. This new disk storage'ssuccessful employment of thin film media and film headsenables it to achieve an areal recording density of 62kbit/mm^2. It will be introduced into the informationprocessing system at NTT in the second quarter of 1987.

4 I0000

HIGH DENSITY MAGNETIC TAPE MEMORY UNITS

Magnetic tape, the earliest form of secondary data storage, lost importance when the magnetic disk became available. The disk's better accessibility of data and related improvements in sorting ability over the serial operating mode of the magnetic tape relegated the tape to a medium for archival storage.

Increased recording densities on magnetic tape, from 800 bits per inch (bpi) to 1600 bpi and even to 6250 bpi, combined with higher tape transport speed (up to 200 inches/sec) have provided data rates usable for data dumps of large disk files. The continuing need for higher capacity and data transfer rates to satisfy backup requirements of emerging new disk storage products is expected to be satisfied by future magnetic tape systems, incorporating improvements in the magnetic media and the

read/write heads similar to those being implemented in magnetic disk improvements.

Tape media may change to smaller and oriented particulates, and higher coercive materials. Vertical recording may also be used with possible lineal densities in excess of 100,000 bits per inch. Heads, to allow the very high densities, could go to thin film design.

Other efforts to develop ultra-high density recording capabilities include a microgap head arrangement. Used in conjunction with chromium-oxide tape, it is reported to have permitted recording densities of 120,000 bits/inch. Extremely high densities of recording are possible with very small record gaps and unoriented tapes with small particles. Recording densities of 40 million bits/square inch at error rates between 10^{-12} and 10^{-15} appear practicable.

The helical scan recording technology commonly used in the television broadcast industry has the highest storage density and lowest cost per gigabyte (Gbyte). A magnetic tape cassette similar to the size of a home video VHS cassette can store 41 Gbytes or the equivalent of 250 half-inch tapes commonly used in main-frame computer centers. A blank cassette costs $80 or $2/Gbyte. To take advantage of this helical scan technology, representatives from various parts of the government, including both NASA (Goddard) and NSA (R53), have cooperated to develop the American National Standard 19mm Type ID-1 Instrumentation Digital Cassette Format, or ANSI X3B6. Sony, a pioneer in this technology for television broadcast stations also designed a robotic library management system that can store, load and unload a large quantity of these cassettes in the record/playback machine. This system design is being further developed into a general purpose data server complete with the required bandwidth and buffering capability for computer applications.

37 I011A
38 I011B
39 I011C
5 I000C

WRITABLE OPTICAL DATA STORAGE DISK UNITS

The video disc, developed initially for the recording and replay of TV programs, movies, and other visual information in the entertainment and training fields, is receiving increasing attention in the data processing/information handling areas for its large storage capacity, small size, and relatively low cost.

In the form of a 12" removable plastic disc, it can be encoded by a laser beam which "burns" small pits, each representing a bit of information, along a continuous groove. It is able to store a 30 minute TV program (about 54,000 color TV frames) or approximately 100,000 pages of 8 1/2" x 11" black and white documents. The potential digital image storage capacity by single or dual sided recording methods presently is in the one to ten gigabyte range.

RCA, Philips, Toshiba, IBM, STC, CDC, and others are working to apply this technology to the field of digital information storage. Recording the scanned image of a document in the form of a bit-stream and reconstructing it for replay, they could serve as electronic document filing systems, with initial cost projections in the $20,000-$50,000 range. A novel approach is already being taken by several vendors who are supplying systems by which personal computers can be converted to, and can control

commercial video disc players for educational, advertising, and training markets. These types of systems are expected to proliferate over the next several years.

The process of recording information by burning pits into the surface of the video disc with a laser beam and the retrieval of such information, is subject to a raw error rate (in the range of 10^-5 to 10^-8) which is several orders of magnitude higher than the error rate experienced with presently used magnetic storage devices. While this error rate may be acceptable for the recording and retrieval of digitally stored images due to the redundancies inherent in such images, it is generally not acceptable for the recording and retrieval of data. Methods for the reduction or compensation of the existing raw error rate under consideration generally lead to a significant trade-off reduction of usable storage capacity. As a result, the estimated available capacity of video discs for the storage of data is much less than the capacity applicable to image storage .

For the laser hole-burning approach, conservative estimates for the storage of digital data expect a capacity of 500 megabytes to one gigabyte for a 12" disc. With the added complexity of the error control logic and indexing in the digital data environment, the cost estimates for single drive systems vary between $25,000 and $120,000. While Toshiba has announced the availability of an initial product, volume availability and acceptance still appears to be three to five years away.

With the anticipated price for a recordable hole-burning type video disc of $150, multi-disc arrangements for shelf storage in "jukebox" format could permit a storage capacity of 10 trillion bits per system at a potential cost of .003 millicent per bit. Access times are likely to range from about 0.1 second to a single disc to about 3 seconds to a "jukebox" of multiple discs. Little effort is seen to reduce access times since the video disc will be used in a storage mode; cost, capacity, and reliability will be the critical variables.

Driven by the need to improve reliability and to increase capacity, the search for ways to enhance electro-optical storage capabilities continues. A new recording technique developed by 3M takes the approach of using a laser beam to heat a base material on the disc and create bubbles or bumps in the surface covering material. Reportedly this playback system can more readily differentiate a blister than other techniques can distinguish a hole in a flat surface.

Another process of considerable promise is reported under development at the IBM research laboratories in San Jose. Called frequency domain storage or photochemical hole burning, it has the potential of storing many bits of information in a single spatial spot. To achieve this effect,a very low temperature environment is required.

Efforts are also directed to determine the potential of electro-photographic material for high density recording digital information.

There are also efforts underway to develop technologies which provide erasable optical storage media. One of them has resulted in the development of a prototype disc by Japan Broadcasting Corporation. Using the thermomagnetic characteristics of a gadolinium-cobalt thin film, it is reported to permit selective erasure as well as erasure of the whole disc by a strong magnetic head.

Video discs are estimated to have a two-year minimum storage life, which may be extendable to ten years and more.

43 I015A

50 I018A A magneto optical mass storage system has been developed which features high performance in speed and compatibility with write-once disks. Optical disk drives, controllers and automatic disk changers can be freely combined, resulting in the highly flexible and extensible system. The system uses 130 mm diameter, 2-sided disks with 524 MB data storage capacity and has a maximum data storage capacity of 13GB. It provides a data transfer rate of 0.92 MB/sec and an access time of less than 65 msec. This is the first optical disk system with high performance which is applicable to information processing for office automation.

40 I012A

SURVEY OF ADVANCED TECHNOLOGIES IN JAPAN

APPENDIX J

HIGH-RESOLUTION FLAT PANEL DISPLAYS (HRFPD)

0205010A00 - HRFPD - SYSTEM PERFORMANCE

0205010A01 - GAS DISCHARGE (PLASMA) DISPLAY PANELS

0205010A02 - ELECTROLUMINESCENT PANEL DISPLAYS

0205010A04 - LIQUID CRYSTAL DISPLAYS

0205010A07 - VACUUM FLUORESCENT DISPLAY PANELS

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
** *** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (1 OF 3)								
02050 10A00	A	BL		B	J0000		Y	
** *** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (2 OF 3)								
02050 10A00	B	BL		B	J0000		Y	
** *** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (3 OF 3)								
02050 10A00	C	BL		B	J0000		Y	
02050 10A00	C	JA	E	P	J001C	P	Y	JAPAN AVIATION ELECTRONICS
** *** SUB-TECHNOLOGY: GAS DISCHARGE (PLASMA) DISPLAY PANELS								
02050 10A01	A	BL		B	J0000		Y	
02050 10A01	A	JA	D	P	J027F	P	N	DIXY CORPORATION (FUJI ELECTRONICS CORPORATION)
02050 10A01	A	JA	D	P	J011A	P	N	FUJITSU LIMITED, COMMUNICATIONS & ELECTRONICS DIVISION
02050 10A01	A	JA	D	S	J010A	J018A	Y	FUJITSU LTD
02050 10A01	A	JA	E	S	J003C	J019A	N	FUJITSU LTD
02050 10A01	A	JA	D	P	J030A	P	N	FUJITSU LTD
02050 10A01	A	JA	D	P	J003B	P	N	FUJITSU LTD
02050 10A01	A	JA	D	P	J012A	P	N	FUJITSU LTD, COMMUNICATIONS & ELECTRONICS

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

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02050 10A01	A	JA	D	P	J013A	P	N	FUJITSU LTD, COMMUNICATIONS & ELECTRONICS
02050 10A01	A	JA	E	S	J010B	J019A	Y	FUJITSU LTD.
02050 10AC1	A	JA	D	P	J019A	P	N	FUJITSU LTD., COMMUNICATION & ELECTRONICS
02050 10A01	A	JA	D	P	J014A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A01	A	JA	D	P	J015A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A01	A	JA	D	P	J016A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A01	A	JA	D	P	J017A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A01	A	JA	D	P	J018A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A01	A	JA	E	P	J001A	P	Y	OKI ELECTRIC INDUSTRY LTD
02050 10A01	A	JA	D	P	J005A	P	Y	SCIENCE & TECHNOLOGY RESEARCH LABORATORIES
** *** SUB-TECHNOLOGY: ELECTROLUMINESCENT PANEL DISPLAYS								
02050 10A02	A	BL		B	J0000		Y	
02050 10A02	A	JA	E	P	J003A	P	N	FUJITSU LTD.

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

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02050 10A02	A	JA	E	P	J001C	P	N	OKI ELECTRIC INDUSTRY CO., LTD
02050 10A02	A	JA	E	P	J027H	P	N	SHARP ELECTRONICS CORPORATION
** *** SUB-TECHNOLOGY: LIQUID CRYSTAL DISPLAYS								
02050 10A04	A	BL		B	J0000		Y	
02050 10A04	A	JA	C	P	J023A	P	Y	FUJITSU LTD, COMMUNICATIONS & ELECTRONICS
02050 10A04	A	JA	B	P	J024A	P	Y	FUJITSU LTD, COMMUNICATIONS AND ELECTRONICS
02050 10A04	A	JA	D	P	J034A	P	N	FUJITSU LTD.
02050 10A04	A	JA	C	P	J020A	P	Y	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A04	A	JA	C	P	J021A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A04	A	JA	C	P	J025A	P	N	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS
02050 10A04	A	JA	C	P	J022A	P	Y	FUJITSU LTD., COMMUNICATIONS AND ELECTRONICS
02050 10A04	A	JA	D	P	J007A	P	N	HITACHI LTD.
02050 10A04	A	JA	C	P	J031C	P	Y	HITACHI LTD.
02050 10A04	A	JA	C	P	J035A	P	Y	HITACHI, LTD., HITACHI RESEARCH LABORATORY

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CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
02050 10A04	A	JA	E	P	J029A	P	Y	JAPAN AVIATION ELECTRONICS (JAE)
02050 10A04	A	JA	E	P	J029B	P	Y	JAPAN AVIATION ELECTRONICS (JAE)
02050 10A04	A	JA	B	P	J002A	P	Y	MITSUBISHI ELECTRIC CORPORATION
02050 10A04	A	JA	B	P	J031D	P	Y	MITSUBISHI ELECTRIC CORPORATION
02050 10A04	A	JA	B	P	J004B	P	Y	NATIONAL AEROSPACE AGENCY OF THE SCIENCE & TECHNOLOGY AGENCY
02050 10A04	A	JA	D	P	J004A	P	N	NATIONAL AEROSPACE LABORATORY OF THE SCIENCE & TECHNOLGY AGENCY
02050 10A04	A	JA	B	P	J031A	P	Y	NEC CORPORATION
02050 10A04	A	JA	E	P	J001D	P	N	OKI ELECTRIC INDUSTRY LTD
02050 10A04	A	JA	D	P	J009A	P	Y	SEIKO EPSON CORPORATION
02050 10A04	A	JA	C	P	J010C	P	N	SEIKO EPSON CORPORATION
02050 10A04	A	JA	B	P	J006A	P	Y	SEIKO EPSON CORPORATION, ELECTRO PACKAGING & DEVELOPMENT SECTION
02050 10A04	A	JA	C	P	J028A	P	N	SEIKO INSTRUMENTS, INC.
02050 10A04	A	JA	C	P	J028B	P	N	SEIKO INSTRUMENTS, INC.
02050 10A04	A	JA	C	P	J033A	P	N	SHARP CORPORATION

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
02050 10A04	A	JA	A	P	J008A	P	Y	SHARP CORPORATION, ELECTRONIC COMPONENTS GROUP
02050 10A04	A	JA	A	P	J027C	P	N	SHARP ELECTRONIC CORPORATION
02050 10A04	A	JA	B	P	J027B	P	N	SHARP ELECTRONIC CORPORATRION
02050 10A04	A	JA	B	P	J027A	P	N	SHARP ELECTRONICS CORPORATION
02050 10A04	A	JA	C	P	J027D	P	N	SHARP ELECTRONICS CORPORATION
02050 10A04	A	JA	B	P	J010D	P	Y	TOSHIBA CORPORATION
02050 10A04	A	JA	B	P	J031E	P	Y	TOSHIBA CORPORATION
02050 10A04	A	JA	A	P	J032A	P	Y	TOSHIBA CORPORATION
02050 10A04	A	JA	A	P	J032B	P	Y	TOSHIBA CORPORATION

** *** SUB-TECHNOLOGY: VACUUM FLUORESCENT DISPLAY PANELS

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
02050 10A07	A	BL		B	J0000		Y	
02050 10A07	A	JA	B	P	J026C	P	N	FUBABA CORPORATION LTD.
02050 10A07	A	JA	D	P	J026D	P	N	FUBATA CORPORATION LTD.
02050 10A07	A	JA	D	P	J026E	P	N	FUBATA CORPORATION LTD.
02050 10A07	A	JA	D	P	J026F	P	N	FUBATA CORPORATION LTD.

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
SUMMARY LISTING OF PRIMARY AND SECONDARY ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL #	SHET	CTRY	RANK	P/S	PAGE NO. HARD COPY	REF # PRIME ENTRY NO.	MEMO	ORGANIZATION 1
02050 10A07	A	JA	D	P	J026G	P	N	FUBATA CORPORATION LTD.
02050 10A07	A	JA	C	P	J026B	P	N	FUBUTA CORPORATION LTD.
02050 10A07	A	JA	B	P	J027E	P	N	FUTABA CORPORATION
02050 10A07	A	JA	C	P	J026A	P	N	FUTABA CORPORATION LTD.

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (1 OF 3)							
02050 10A00 A HRFPD	NONE (SEE OTHER CTLS) --- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF
** ******************** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (2 OF 3)							
02050 10A00 B HRFPD	NONE (SEE OTHER CTLS) --- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF
** ******************** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (3 OF 3)							
02050 10A00 C HRFPD	NONE (SEE OTHER CTLS) --- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	--- --- IMPR. DIR:	SYS PERF
** ******************** SUB-TECHNOLOGY: GAS DISCHARGE (PLASMA) DISPLAY PANELS							
02050 10A01 A HRFPD	RESOLUTION (HORIZ x VERT) --- LINES --- IMPR. DIR: H	SCREEN SIZE (DIAGONAL) --- CENTIMETERS (CM) --- IMPR. DIR: H	VIEWING ANGLE --- DEGREES --- IMPR. DIR: H	CONTRAST RATIO --- NONE --- IMPR. DIR: H	DISPLAY PANEL TECHNOLOGY --- NONE --- IMPR. DIR: X	TOUCHSCREEN TECHNOLOGY --- NONE --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: ELECTROLUMINESCENT PANEL DISPLAYS							
02050 10A02 A HRFPD	RESOLUTION (HORIZ x VERT) --- LINES --- IMPR. DIR: H	SCREEN SIZE (DIAGONAL) --- CENTIMETERS (cm) --- IMPR. DIR: H	VIEWING ANGLE --- FRAMES/SECOND --- IMPR. DIR: H	CONTRAST RATIO --- NONE --- IMPR. DIR: H	DISPLAY PANEL TECHNOLOGY --- NONE --- IMPR. DIR: X	TOUCHSCREEN TECHNOLOGY --- NONE --- IMPR. DIR: X	COMP

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LIST OF PARAMETER NAMES, AND UNITS FOR EACH SUB-TECHNOLOGY
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL # SHEET TECH CODE	PARAMETER 1 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 2 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 3 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 4 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 5 NAME: --- UNITS: --- DIR. TO IMPROVE:	PARAMETER 6 NAME: --- UNITS: --- DIR. TO IMPROVE:	TECH CAT:
** ******************** SUB-TECHNOLOGY: LIQUID CRYSTAL DISPLAYS							
02050 10A04 A HRPFD	RESOLUTION (HORIZ x VERT) --- LINES --- IMPR. DIR: H	SCREEN SIZE (DIAGONAL) --- CENTIMETERS (cm) --- IMPR. DIR: H	VIEWING ANGLE --- DEGREES --- IMPR. DIR: H	CONTRAST RATIO --- NONE --- IMPR. DIR: H	DISPLAY PANEL TECHNOLOGY --- NONE --- IMPR. DIR: X	TOUCHSCREEN TECHNOLOGY --- NONE --- IMPR. DIR: X	COMP
** ******************** SUB-TECHNOLOGY: VACUUM FLUORESCENT DISPLAY PANELS							
02050 10A07 A HRFPD	RESOLUTION (HORIZ x VERT) --- LINES --- IMPR. DIR: H	SCREEN SIZE (DIAGONAL) --- CENTIMETERS (cm) --- IMPR. DIR: H	VIEWING ANGLE --- DEGREES --- IMPR. DIR: H	CONTRAST RATIO --- NONE --- IMPR. DIR: H	DISPLAY PANEL TECHNOLOGY --- NONE --- IMPR. DIR: X	TOUCHSCREEN TECHNOLOGY --- NONE --- IMPR. DIR: X	COMP

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS (3 OF 3)												
02050 10A00 C HRFPD 20	B	JAPAN AVIATION ELECTRONICS ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	----	----	----	----	----	----	JAU/MSG 2887-81 53/02 03/24/8 7 J001C / / JA
** *************** SUB-TECHNOLOGY: GAS DISCHARGE (PLASMA) DISPLAY PANELS												
02050 10A01 A HRFPD 54	D	DIXY CORPORATION (FUJI ELECTRONICS CORPORATION) ---- TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x40 0 ----	---- VIEWIN G AREA - (10.08 6x6.30 in)	115 ----	----	PWM ----	----	JEB/08- 18-88/0 146 08/18/8 8 J027F / / JA
02050 10A01 A HRFPD 27	D	FUJITSU LIMITED, COMMUNICATIONS & ELECTRONICS DIVISION ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	240x80 ---- FPF400 8NRUF DOT GRAPHI C TYPE PANEL	---- 14.34x 4.7 cm	120 ----	20:1 ----	----	----	JEI/BRO CHURE/0 01 01/01/8 9 J011A / / JA
02050 10A01 A HRFPD 60	D	FUJITSU LTD ---- 6-1, MARUNOUCHI CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x40 0 ---- 10,000 HOUR OPERAT ING LIFE. 0.33mm PITCH	----	----	20:1 ----	----	----	JEO/AD A189 294/2-3 8 05/01/8 7 J030A 05/01/8 7 JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	MESTPHSE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A01 A HRFPD 24	D	FUJITSU LTD ---- 6-1 MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM COMPANY BROCHURE	---- ---- ----	---- ---- ----	N A FP U	---- ARTICLE GIVES ONLY LIMITED INFORMATION AS TO THEIR PARTICIPATION	20.32 ---- 3 COLOR	----	----	----	----	JDU/10-01-88/0 07 10/01/8 8 J003B / / JA
02050 10A01 A HRFPD 28	D	FUJITSU LTD, COMMUNICATIONS & ELECTRONICS ---- 6-1MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	40x12 ---- FPC401 2NRUL ALL-ICED CHARACTER TYPE	---- 16.5x7 .74cm	120 ----	50:1 ----	----	----	JEI/BRO CHURE/0 01 01/01/8 9 J012A / / JA
02050 10A01 A HRFPD 29	D	FUJITSU LTD, COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURES	---- ---- ----	---- ---- ----	N A FP U	320x120 ---- FPF401 5NRUF DOT GRAPHIC TYPE	---- 19.14x 7.14cm	>120 ----	20:1 ----	----	----	JEI/BRO CHURE/0 01 01/01/8 9 J013A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A01 A HRFPD 35	D	FUJITSU LTD., COMMUNICATION & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	1024x768 ---- FPF120 0S	---- 30.7x23cm	----	----	----	----	JEI/BROCHURE/001 01/01/89 J019A / / JA
02050 10A01 A HRFPD 30	D	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x400 ---- FPF8050HRUK DOT GRAPHICS WITH 4 GRAY SCALE	---- 21.1x13.2cm	120 ----	20:1 OR MORE ----	----	----	JEI/BROCHURE/001 01/01/89 J014A / / JA
02050 10A01 A HRFPD 31	D	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x400 ----	---- 21.1x13.2 cm	120 ----	20:1 ----	----	----	JEI/BROCHURE/001 01/01/90 J015A / / JA
02050 10A01 A HRFPD 32	D	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM COMPANY BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x400 ---- AYS	---- 21.1x13.2cm	120 ----	20:1 ----	----	----	JEI/BROCHURE/001 01/01/89 J016A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A01 A HRFPD 33	D	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x480 ---- FPF806 OHRUK DOTS GRAPHIC WITH 4 GRAY SCALE	---- 21.1x15.8cm	120 ----	20:1 ----	----	----	JEI/BROCHURE/001 01/01/89 J017A / / JA
02050 10A01 A HRFPD 34	D	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x480 ---- FPF806 OHRUM DOTS GRAPHIC DISPLAY	---- 21.1x15.8	120 ----	20:1 ----	----	----	JEI/BROCHURE/001 01/01/89 J018A / / JA
02050 10A01 A HPFPD 5	E	OKI ELECTRIC INDUSTRY LTD ---- OKYO 105, JAPAN ---- ---- EXERPTS TAKEN FROM 8/86 TRIP REPORT BY UNDER SECRETARY OF DEFENSE	---- ---- ----	---- ---- ----	Y A FP U	---- ARTICLE INDICATED ACTIVITY IN THIS TECHNOLOGY	----	----	----	----	----	JAU/MSG 2887-8153/01 03/24/87 J001A 08/01/86 JA
02050 10A01 A HRFPD 10	D	SCIENCE & TECHNOLOGY RESEARCH LABORATORIES ---- NHK, TOKYO 108, JAPAN ---- H.MURAKAMI, T.KURIYAMA, M.SEKI, T.KATOH ---- ADDITIONAL NAMES- T.YAMAMOTO & Y. MIYATA	SCIENCE & TECHNOLOGY RESEARCH LABORATORIES ---- NHK, TOKYO 108, JAPAN ---- H.NAKAGAWA, T.TAKAHATA, A.ISHIKAWA, ----	SCIENCE & TECHNOLOGY RESEARCH LABORATORY ---- NHK, TOKYO 108, JAPAN ---- K.HIRAKATA, R.KANEKO, Y.TAKANO, T.SAKAI ----	Y A DT U	448x640 ----	50.8 ----	----	90:1 ----	PPM ----	----	JAG/VOL 36 #6/1063 06/01/89 J005A 08/18/88 JA

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CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** *************** SUB-TECHNOLOGY: ELECTROLUMINESCENT PANEL DISPLAYS												
02050 10A02 A HRFPD 7	E	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- ADVERTISEMENT	---- ---- ----	---- ---- ----	N A FP U	---- THIN FILM ELECTR OLUMIN ESCENT DISPLA Y 8" 3-COLO R DISPLA Y	----	----	----	----	----	JDU/10-01-88/0 07 10/01/8 8 J003A / / JA
02050 10A02 A HRFPD 22	E	OKI ELECTRIC INDUSTRY CO., LTD ---- 7-12, TORANOMON 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- EXERPT TAKEN FROM 8/86 TRIP REPORT OF THE U.S. UNDER SECRETARY OF DEFENSE	---- ---- ----	---- ---- ----	N A FP U	---- ARTICL E ONLY INDICA TES OKI'S PARTIC IPATIO N IN THIS ACTIVI TY	----	----	----	----	----	JAU/MSG -2887-8 153/01 03/24/8 8 J001C / / JA
02050 10A02 A HRFPD 55	E	SHARP ELECTRONICS CORPORATION ---- ?, JAPAN ---- ---- ENTRY INDICATES PARTICIPATION IN THIS TECHNOLOGY	---- ---- ----	---- ---- ----	N A FP U	----	----	----	----	ACTFEL ----	----	JEB/08-18-88/0 146 08/18/8 8 J027H / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############### SUB-TECHNOLOGY: LIQUID CRYSTAL DISPLAYS												
02050 10A04 A HRPFD 39	C	FUJITSU LTD, COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	Y A FP U	640x400 ---- FLC640-400BEUA	---- 21.1x15.8	40 ----	1:5 ----	TRANSMISSIVE STN ----	----	JEI/BROCHURE/001/01/90 J023A / / JA
02050 10A04 A HRPFD 40	B	FUJITSU LTD, COMMUNICATIONS AND ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	Y A FP U	640x400 ---- FLC640-400WSUA BLACK & WHITE MODE	---- 21.1x15.7	40 ----	1:15 ----	DSTN-CCFL ----	----	JEI/BROCHURE/001/01/89 J024A / / JA
02050 10A04 A HRPFD 68	D	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	40x12 ---- FOR TINY LAPTOP COMPUTER	----	----	----	----	----	JBD/VOLXII #1/008 01/01/90 J034A 01/01/90 JA
02050 10A04 A HRPFD 36	C	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100 ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	Y A FP U	640x200 ---- FLC640-200BEUA TRANSMISSIVE STN	3.3 ----	40 ----	1:5 ----	STN ----	----	JEI/BROCHURE/001/01/89 J020A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRPFD 37	C	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x200 ---- FLC640-200YRUA	---- 21.1x15.8	40 ----	1:4.5 ----	STN ----	----	JEI/BROCHURE/001 01/01/89 J021A / / JA
02050 10A04 A HRPFD 41	C	FUJITSU LTD., COMMUNICATIONS & ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x400 ---- FLC640-400YRUA REFLECTIVE STN	---- 21.1 x 15.8	40 ----	1:3 ----	REFLECTIVE STN ----	----	JEI/BROCHURE/001 01/01/89 J025A / / JA
02050 10A04 A HRPFD 38	C	FUJITSU LTD., COMMUNICATIONS AND ELECTRONICS ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	Y A FP U	640x400 ---- FLC640-400BCUB TRANSMISSIVE STN WITH CCFL	2.58 ----	40 ----	1:5 ----	STN-CCFL ---- CCFL-COLD CATHODE FLUORESCENT LAMP	----	JEI/BROCHURE/001 01/01/89 J022A / / JA
02050 10A04 A HRPFD 12	D	HITACHI LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	114,720 ----	12.7 ----	----	----	SI TFT ----	----	JBK/OTRLY MAG/054 / / J007A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRPFD 62	C	HITACHI LTD. ---- 6, KANDA-SURUGADAI 4-CHOME, CHIYODA-KU, TOKYO 101 JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	640x20 0 ----	16 ----	----	----	TFT ----	----	JET/10- 31-89/0 36 10/31/8 9 J031C / / JA
02050 10A04 A HRPFD 69	C	HITACHI, LTD., HITACHI RESEARCH LABORATORY ---- HITACHI, IBARAKI, JAPAN ---- Y.NAGAE, E.KANEKO, Y.MORI, H.KAWAKAMI ----	HITACHI, LTD., OMIKA WORKS ---- HITACHI, IBARAKI, JAPAN ---- T. HASHIMOTO ----	---- ---- ----	Y A DT U	1000x1 000 ----	----	----	8:1 ----	RGB ----	----	JEW/VOL 28 #1/ 055 01/01/8 7 J035A / / JA
02050 10A04 A HRPFD 58	E	JAPAN AVIATION ELECTRONICS (JAE) ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	---- 120 DOTS/I NCH	---- 5x5 INCH	----	----	----	YES ----	JEQ/AD- A189 294/2-4 2 05/01/8 7 J029A 01/01/8 5 JA
02050 10A04 A HRPFD 59	E	JAPAN AVIATION ELECTRONICS (JAE) ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD U	---- 150 DOTS/I NCH	---- 6.7 x 6.7"	----	----	----	YES ----	JEQ/AD- A189 294/2-4 2 05/01/8 7 J029B / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRPFD 6	B	MITSUBISHI ELECTRIC CORPORATION ---- MISTUBISHI DENKI BLDG, 2-3 MARUNOUCHI 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	----	25.4 ---- 10 INCH SCREEN	----	----	Si NITRAT E FILM ----	----	JAK/VOL 7 #25/008 03/01/8 8 J002A / / JA
02050 10A04 A HRPFD 63	B	MITSUBISHI ELECTRIC CORPORATION ---- MITSUBISHI DENKI BLDG., 2-3 MARUNOUCHI, 2-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y A DT U	640x48 0 ----	25.4 ----	----	----	TFT ----	----	JET/10-31-89/0 36 10/31/8 9 J031D / / JA
02050 10A04 A HRPFD 9	B	NATIONAL AEROSPACE AGENCY OF THE SCIENCE & TECHNOLOGY AGENCY ---- 1-880, JINDAJI, CHOFU, TOKYO 182, JAPAN ---- ----	YOKOGAWA ELECTRIC CORPORATION ---- 9-32, NAKACHO 2-CHOME, MUSASHINO-SHI, TOKYO 180, JAPAN ---- ----	JAPAN AVIATION ELECTRONICS INDUSTRY ---- 21-6, 1-CHOME, DOGENZAKA, SHIBUYA-KU, TOKYO 150, JAPAN ---- ---- OTHER MANUFACTURERS HAVE BEEN INVITED TOI PARTICIAPTE BUT NOT MENTIONED BY NAME	Y P DT U	----	20.54 ---- 10"	----	----	----	----	JAJ/09-08-89/0 08 09/08/8 9 J004B / / JA
02050 10A04 A HRPFD 8	D	NATIONAL AEROSPACE LABORATORY OF THE SCIENCE & TECHNOLGY AGENCY ---- 1-880, JINDAJI, CHOFU, TOKYO 100, JAPAN ---- ----	YOKOGAWA ELECTRIC CORPORATION ---- 9-32, NAKACHO 2-CHOME, MUSASHINO-SHI, TOKYO 180, JAPAN ---- ---- MAKE - LIQUID CRYSTAL DISPLAY	SEIKO EPSON COPPORATION ---- SUWA CITY, NAGANO PREFECTURE, JAPAN ---- ---- MAKE - MAKES LIQUID DISPLAY PART	N A DT U	----	12.7 ----	----	----	----	----	JAJ/09-08-89/0 10 09/08/8 9 J004A / / JA

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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRPFD 61	B	NEC CORPORATION ---- NEC BLDG., 33-1, SHIBA 5-CHOME, MINATO-KU, TOKYO 108, JAPAN ---- ---- PROBLEMS NOTED WITH SSEE MEMO	---- ---- ----	---- ---- ----	Y A FP U	640x400 ---- FOR PROSPE EDCSX LAPTOP	25.4 ----	30 ----	15:1 ----	DSTN ----	----	JES/10-31-89/036 10/31/89 J031A / / JA
02050 10A04 A HRPFD 23	E	OKI ELECTRIC INDUSTRY LTD ---- 7-12, TORANOMON 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- EXERPT TAKEN FROM 8/86 TRIP REPORT BY THE UNDER SECRETARY OF DEFENSE TO JAPAN	---- ---- ----	---- ---- ----	N A FP U	---- ARTICLE ONLY INDICATES OKI'S PARTICIPATION IN THIS TECHNOLOGY	----	----	----	----	----	JAU/MSG-2887-8153/01 03/24/87 J001D / / JA
02050 10A04 A HRPFD 14	D	SEIKO EPSON CORPORATION ---- OWA, 3-3-5, SUWA, NAGANO, 392 JAPAN ---- S.ARUGA,N.SHIMOTOME,H.OHSHIMA,S MOROZUMI ----	---- ---- ----	---- ---- ----	Y A DT U	70.4 ---- SEE MEMO	2.28 ----	80 ----	> 150 ----	POLY-Si TFT ----	----	JDW/10-04-88/0236 10/04/88 J009A / / JA
02050 10A04 A HRPFD 21	C	SEIKO EPSON CORPORATION ---- 3-5, OWA 3-CHOME, SUWA-SHI, NAGANO-KEN, 392, JAPAN ---- HIROSHI WATANABE ----	---- ---- ----	---- ---- ----	N A DT U	240 x 480 ----	12.19 ----	60 ----	30:1 ----	----	----	JEA/10-01-88/087 10/01/88 J010C / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
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DATABASE ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRPFD 11	B	SEIKO EPSON CORPORATION, ELECTRO PACKAGING & DEVELOPMENT SECTION ---- 3-5, OWA 3-CHOME, SUWA-SHI, NAGANO-KEN, 392, JAPAN ---- H.MASUDA, K.SAKUMA, E. SATOH, Y.YAMASAKI ----	SEIKO EPSON CORPORATION, RESEARCH & DEVELOPMENT DIVISION ---- 3-5, OWA 3-CHOME, SUWA-SHI, NAGANO-KEN, 392, JAPAN ---- H. MIYASAKA ----	SEIKO EFSON CORPORATION, LD PRODUCTION PLANNING CHEAM. LCD DIVIDION ---- 3-5, OWA 3-CHOME, SUWA-SHI, NAGANO-KEN, 392, JAPAN ---- J. TAKEUCHI ----	Y A DT U	640 x 480 ----	30.48 ---- 12"	---- SEE MEMO	----	NTN ----	----	JAJ/08-24-89/0 27 08/24/8 9 J006A / / JA
02050 10A04 A HRPFD 56	C	SEIKO INSTRUMENTS, INC. ---- 31-1, KAMEIDO, 6-CHOME, KOTOKU, TOKYO 136, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x400 ---- MODEL G644F	----	---- WIDE	----	STN ----	----	JEL/PRODUCT BROC./01 08/01/8 9 J028A / / JA
02050 10A04 A HRPFD 57	C	SEIKO INSTRUMENTS, INC. ---- 31-1, KAMIDO, 6-CHOME, KOTOKU, TOKYO 136, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x200 ---- MODEL G648D	----	----	----	STN ----	NONE ----	JEK/PRODUCT BROC/01 08/01/8 9 J028B / / JA
02050 10A04 A HRPFD 67	C	SHARP CORPORATION ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A DT U	---- 921,600 PIXELS	25.40 ----	----	----	TFT ----	----	JBD/VOL XI #52/008 12/25/8 9 J033A / / JA

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DATABASE ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

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02050 10A04 A HRPFD 13	A	SHARP CORPORATION, ELECTRONIC COMPONENTS GROUP ---- 2613-1 ICHINOMOTO, TENRI-CITY, NARA 632, JAPAN ---- T.NAGAYASU, T.OKETANI, T.HIROBE, H.KATO ----	SHARP CORPORATION, ELECTRONICS COMPONENTS GROUP ---- 2613-1 ICHINOMOTO, TENRI-CITY, NARA 632, JAPAN ---- S.MIZUSHIMA, H.TAKE, K.YANO ----	SHARP CORPORATION, ELECTRONIC COMPONENTS GROUP ---- 2613-1 ICHINOMOTO, TENRI-CITY, NARA 632, JAPAN ---- M.HIJIKIGAWA & T. WASHIZUKA ----	Y A DT U	308,160 ----	35.56 ----	120 ---- HORIZONTAL VEIWING ANGLE	100:1 ----	SI-TFT ----	----	JDW/10-04-88/056 10/04/88 J008A / / JA
02050 10A04 A HRPFD 51	A	SHARP ELECTRONIC CORPORATION ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	720x400 ---- DOT MATRIX MONOCHROME	---- VIEWING AREAS-10.24x5.79IN.	----	----	DSTN ----	----	JEB/08-18-88/0140 08/18/88 J027C / / JA
02050 10A04 A HRPFD 50	B	SHARP ELECTRONIC CORPORATRION ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x480 ---- DOT MATRIX MONOCHROME	---- VIEWING AREA 9.338x7.09	----	---- HIGH CONTRAST	DSTN ----	----	JEB/08-18-88/0140 08/18/88 J027B / / JA
02050 10A04 A HRPFD 49	B	SHARP ELECTRONICS CORPORATION ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x400 ---- DOT MATRIX MONOCHROME	---- VIEWING AREA 8.589x5.476IN.	----	---- OFFERS HIGH CONTRAST	DSTN ----	----	JEB/08-18-88/0140 08/18/88 J027A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
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CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRPFD 52	C	SHARP ELECTRONICS CORPORATION ---- ?, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	384x240 ---- COLOR DISPLAY USED WITH THE IBM VGA	7.62 ----	----	----	ACTIVE MATRIX TFT ----	----	JEB/08-18-88/0140 08/18/88 J027D / / JA
02050 10A04 A HRPFD 26	B	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A DT U	639x400 ----	30.48 ----	----	>10:1 ----	SMECTIC C PHASE ----	NONE ----	JEA/10-01-88/091 10/01/88 J010D / / JA
02050 10A04 A HRPFD 64	B	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- SEE MEMO	---- ---- ----	---- ---- ----	Y P FP Y	---- JOINT VENTURE WITH IBM	25.4 ----	----	----	TFT ----	----	JET/10-31-89/036 10/31/89 J031E 04/01/91 JA
02050 10A04 A HRPFD 65	A	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- TEAM WITH IBM JAPAN	---- ---- ----	---- ---- ----	Y A DT U	1440x1100 ---- FOR MONOCHROME	36.22 ----	----	----	----	----	JDQ/10-01-89/017 10/01/89 J032A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
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DATABASE ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A04 A HRFPD 66	A	TOSHIBA CORPORATION ---- 1-1, SHIBAURA 1-CHOME, MINATO-KU, TOKYO 105, JAPAN ---- ---- TEAMED WITH IBM JAPAN	---- ---- ----	---- ---- ----	Y A DT U	720x55 0 ---- IN COLOR	36.22 ----	----	----	----	----	JDO/10- 01-89/0 17 10/01/8 9 J032B / / JA
** ############### SUB-TECHNOLOGY: VACUUM FLUORESCENT DISPLAY PANELS												
02050 10A07 A HRFPD 44	B	FUBABA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	640x40 0 ---- TYPE:G P1019A 0	---- DIMENS ION: 170x18 0x65mm	----	----	FLVFD ----	----	JAJ/BRO CHURE/0 02 01/01/8 9 J026C / / JA
02050 10A07 A HRFPD 45	D	FUBATA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	128x64 ---- TYPE:G P1005B 0	---- DIMENS IONS:8 5x185x 45mm	----	----	VFD ----	----	JEJ/BRO CURE/00 2 01/01/8 9 J026D / / JA
02050 10A07 A HRFPD 46	D	FUBATA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	256x64 ---- TYPE:G P1006B 0	---- 85x250 x45mm	----	----	VFD ----	----	JEJ/BRO CHURE/0 02 01/01/8 9 J026E / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL # SHEET CODE REC #	RANK	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
02050 10A07 A HRFPD 47	D	FUBATA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	240x64 ---- TYPE:G P1009A 0	---- DIMENS IONS:7 0x158x 40	----	----	VFD ----	----	JEJ/BRO CHURE/0 02 01/01/8 9 J026F / / JA
02050 10A07 A HRFPD 48	D	FUBATA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	176x16 ---- TYPE:G P10103 0	---- DIMENS ION: 60x186 x41 mm	----	----	----	----	JEJ/BRO CHURE/0 02 01/01/8 9 J026G / / JA
02050 10A07 A HRFPD 43	C	FUBUTA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	400x24 0 ---- TYPE-G P1018A 0	---- DIMENS ION 160x18 0x41mm	----	----	----	----	JEJ/BRO CHURE/0 02 01/01/8 9 J026B / / JA
02050 10A07 A HRFPD 53	B	FUTABA CORPORATION ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ----	---- ---- ----	---- ---- ----	N A FP U	640x40 0 ---- MODEL- GP1019 A03A 3-COLO RS	---- DISPLA Y AREA 4.72x3 .54IN	----	----	----	----	JEB/08- 18-88/0 141 08/18/8 8 J027E / / JA
02050 10A07 A HRFPD 42	C	FUTABA CORPORATION LTD. ---- 629 OSHIBA, MOBARA, CHIBA 297, JAPAN ---- ---- INFORMATION OBTAINED FROM PRODUCT BROCHURE	---- ---- ----	---- ---- ----	N A FP U	320x24 0 ---- MODEL GP1002 CO	---- DIMENS ION 160x18 0x41mm	----	----	----	----	JEJ/BRO CHURE/0 02 01/01/8 9 J026A / / JA

TECHNOLOGY ASSESSMENT OFFICE - TRW SPECIAL PROGRAMS
JAPANESE TECHNOLOGY STUDY
DATABASE ENTRIES FOR SECONDARY REPORTS
TECHNOLOGY: HIGH-RESOLUTION FLAT PANEL DISPLAYS

CTL # SHEET CODE REC #	R A N K	ORGANIZATION 1 LOCATION, PERSON, COMMENTS	ORGANIZATION 2 LOCATION, PERSON, COMMENTS	ORGANIZATION 3 LOCATION, PERSON, COMMENTS	ME ST PH SE	PAR 1 VALUE NOTES	PAR 2 VALUE NOTES	PAR 3 VALUE NOTES	PAR 4 VALUE NOTES	PAR 5 VALUE NOTES	PAR 6 VALUE NOTES	SOURCE INFO DT PAGE ID WDT,CTY
** ############## SUB-TECHNOLOGY: GAS DISCHARGE (PLASMA) DISPLAY PANELS												
02050 10A01 A J018A HRFPD 15	D	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y A FP U	640 x 480 ----	26.42 ----	120 ----	20:1 ----	----	----	JEA/VOL 60 # 742/099 10/01/8 8 J010A / / JA
02050 10A01 A J019A HRFPD 25	E	FUJITSU LTD ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ---- INFORMATION OBTAINED FROM COMPANY BROCHURE	---- ---- ----	---- ---- ----	N A FP U	1020x7 68 ----	38.1 ----	----	----	----	----	JDU/10- 01/98/0 07 10/01/8 8 J003C / / JA
02050 10A01 A J019A HRFPD 16	E	FUJITSU LTD. ---- 6-1, MARUNOUCHI 1-CHOME, CHIYODA-KU, TOKYO 100, JAPAN ---- ----	---- ---- ----	---- ---- ----	Y P RD	1024 x 768 ----	----	----	----	----	----	JEA/VOL 60 # 742/099 10/01/8 8 J010B / / JA

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1 J0000

HIGH-RESOLUTION FLAT PANEL DISPLAYS

High resolution flat panel displays are a special configuration of the familiar display screen that is part of the typical personal computer (PC), and are most similar to those displays used in lap-top computers. They generally have the same display capabilities as the average PC, which includes alphanumerics and graphics. Their character generation also accepts user definable fonts and their graphics includes points, vectors (lines), arcs, circles, rectangles, polygons and polygon fills.

They are finding applications in:

A. Computer terminals
B. Air traffic control
C. Airborne command post
D. Aircraft instrumentation
E. Naval shipboard systems
F. Intelligence information display
G. Tactical computer systems
H. Integrated fire support systems
I. Telemetry integrated processing systems
J. Radar and Sonar systems
K. Satellite communications systems
L. Briefcase terminals and computers
M. CAD/CAM systems

The displays employed in most of these applications incorporate a feature not found in the common PC display, called touchscreen technology, which permits the user to communicate with the computer by touching the display screen.

Touchscreen Technologies

Scanning IR

Uses a large quantity of light emitting diodes and corresponding IR photodetectors, mounted 1/4 inch apart, along both dimensions of the screen. Software provides a resolution of 1/8 inch. A finger touching the screen will interrupt the signals of LEDs in both axes and will be converted by software to a set of screen coordinates. Because these LEDs and detectors are mounted in a bezel or frame in front of the screen surface, the IR beams they utilize do not require any coating or film on the screen surface, and could be used with these flat panel displays or with conventional cathode ray tube (CRT) displays in either monochrome or color. They do not provide a tactile feedback, and while they are reliable, they are also expensive because of their inherently high parts count.

Capacitive Touchscreens

These have a transparent coating of indium tin oxide (ITO) on both the inside and outside surfaces of the glass surface of the display panel. Often the outside surface has an overcoat of tin antimony oxide (TAO) for improved wear resistance. In operation, the frequencies of 4 oscillator circuits, located in the panel corners are established by a low level current in this capacitive panel. The body impedance of a person touching the panel alters these frequencies. They use 8-bit controllers to obtain resolutions of 256 x 256 touch points. They are very sensitive to electronic noise and cannot be used with plasma displays.

Resistive Membranes

These have the highest resolution (up to 4,096 x 4,096) and the lowest cost. The analog resistive-membrane consists of a clear conductive film over the surface of a clear glass or plastic panel, separated by an array of tiny transparent elastic dots. The film overlay is either polycarbonate (Lexan) or oriented polyester (Mylar). The facing surfaces of the film and clear panel are coated with a conductive material such as indium tin oxide (ITO). Voltage travels alternately along the X and Y axes accross the touch screen, while the opposite edges are alternately grounded, thus creating a uniform voltage gradient across the screen. When the screen is touched, the conductive film layer - acting as a voltage probe - touches the bottom layer, causing electrical contact to be made and a voltage measurement to be sent to the controller, registering the touch coordinates.

Surface Acoustic Wave (SAW) Touchscreen

SAW touchscreens have the second highest resolution, up to 100 touch points per inch, and can either be a separate panel or can be built into the bezel of a CRT or flat panel display. They utilize the ability of inaudible high-frequency acoustic wave to travel over a glass surface at very precise speeds in very straight lines. The system uses 2 transmitting transducers and 2 receiving transducers, one each for the X and Y axes, located in corners of the screen. The piezoelectric transmitter located in the upper left corner, for the X axis, transmits a signal along the top edge of the screen through a relflective array of parallel, diagonal lines printed on the glass surface. The signal is partially reflected, down across the screen, by each line and the remainder transmitted to the next line. A similar pattern at the bottom of the screen collects these signals and reflects them to the receivng transducer in the bottom left corner. A finger touching the screen blocks signals in both axes. By calculating the the speed of the sound waves a controller calculates the touch coordinates.

17 J0003 HIGH-RESOLUTION FLAT PANEL DISPLAYS (PART 2)

A Flat panel display is an electronic display with a package thickness (from 0.5 in to 2.5 in) that is a fraction of the displays height or length. The electronics sometimes accounts for a significant portion of the total thickness. Flat panel displays have a long way to go before they supplant cathode-ray tubes (CRT)s, which are comparatively inexpensive, and have the best color capability, resolution, brightness, contrast, and general visibility. Their main disadvantages are bulkiness, weight, and high power requirements. The principal flat panel display technologies are: Liquid Crystal Displays (LCD), Electroluminescent Displays (ELD), Plasma Display Panels (PDP), and Vacuum Fluorescent Displays (VFD). A glossary of flat panel display terms follows.

Acuity - The uniformity of light emission across a pixel and its degree of edge definition. Asssuming the contrast ratio is high enough for easy distinction of off and on-pixels, the uniformity of emmission of the on-pixels, together with the size and shape of the pixels themselves, dictates the sharpness of the images.

Aspect ratio - The ratio of the display's width to its height.

Birefringence -- Double refraction. The splitting of a light beam into two light waves when the beam enters a crystal. The resultant two light waves vibrate in directions that are perpendular to each other.

Brightness -- The light-intensity, or luminosity, of the display. Brightness is measured in foot lamberts(fL), or in candelas per meter squared (cd/m^2). Note: cd/m^2 = 0.292 fL.

CGA -- Golor - graphics adapter. An electronic display standard that species a resolution of 640 x 200 pixels in the 2-color mode, and 320 x 200 pixels in the 4-color mode (from a palette of 16 colors). The horizontal scanning frequency is specfied as 15.75 kHz.

Contrast Ratio - The ratio of on-pixel brightness compared to the off pixel brightness. It represents the difference in light intensity between the foreground and background of a display. Black and white provide the ideal contrast. Depending on the type of display, contrast ratios for flat-panel displays vary from a value of less than 3:1 for some LCD types, to values of 20:1 or more for some ELD types. The perceived contrast depends on the ambient light, but a contrast of about 7:1 is generally considered as an acceptable ratio. Above a ratio of about 15:1, the human eye perceives little difference in contrast.

Controller -- A pc board that goes behind the display (or in the computer bus). The controller lets the computer communicate with the display. For a CRT raster-scan display, the controller provides the signals needed for horizontal sync, vertical sync, and serial data. Flat-panel diplays usuall require an additional signal - the dot-clock signal - to control the transfer speed of the pixel information.

CRT - Cathode-Ray tube - An electron tube used in TV receivers, oscillscopes, radar equipment, and computer equipment to display data. Usually rectangular with a 4:3 aspect ratio, CRTs' diagonal measurement ranges generally from about 5 to 28 in. The diagonal of CRT monitors for computers or video terminals are typically between 12 and 14 in.

Display size -- The illuminated area of the display that is available for viewing data. Manufacturers of CRTs usually measure them according to their diagonal sizes. For flat-panel displays, manufacturers usually specifiy the height and width.

(SEE NEXT SCREEN OF HRFPD FOR TUTORIAL CONTINUATION)

18 J000C

HIGH-RESOLUTION FLAT PANEL DISPLAYS (PART 3)

Dithering - A computer-graphics technique used to provide shading by turning points on a pixel on and off. In monochrome plasma displays, for example, each pixel can consist of a cluster of four points (sub-pixels), each of which can be on or off. By turning these sub-pixels on in various combinations, the plasma display can show four levels of brightness, or gray-scale shading.

Dot-clock signal - The signal that controls the pixel rate for the display system. Digital technologies, such flat-panel displays, require this signal to tell the host system how fast to read the individual pixel information from the system to the panel. This signal is not required for CRT analog displays.

Duty cycle - Response time. The amount of time it takes for an electronic display to refresh every pixel on the screen. The minimum acceptable time is about 16.6 msec, which corresponds to a minimum refresh rate of 60 Hz. At refresh rates slower than about 60 Hz, the human eye begins to detect a flicker in the display.

EGA -- Enhanced-graphics adapter. An electronic display standard that specifies a resolution of 640 x 350 pixels with 16 color capabity (from a palette of 64 colors). Included in this standard are 80- and 40 colunm text modes, and CGA emulation.

Fill factor - The percentage of the total area of the display that is luminated at any given time, comparedwith the surrounding nonilluminated area. Displays with a low fill factor (20%) tend to look like a collection of dots. Displays with fill factors of 50% or more exhibit greater apparent brightness and are generally more readable and aesthetically pleasing.

Pixel -- A picture element. The smallest unit of a video display. In CRT applications, the pixel's color and intensity is coded into an electrical signal for transmission from the system to the display. For flat-panel displays, pixels and dots are interchangeable.

Resolution -- A number of factors determime the real or visually apparent resolution. These factors include the pixel (dot) size and pitch, the number of lines per inch, and the total number of pixels. Although the type of display (ELD, LCD, PDP) can have a significant effect on the apparent resolution because of differences in contrast and brightness, the best quantitative measurement is probably the total pixel count in a 4-value scale.

Sparkling - A computer-graphics technique that turns off a pixel every other time the screen is refreshed. Unlike CRTs, which typically use high-persistence phosphor, flat-panel displays turn off when the power to a pixel is removed. Sparkling can provide a 2-value gray screen that is satisfactory for a monochrome display or the 2-color 640x200 pixel CGA mode. For the 4-color 320x200-pixel CGA mode, flat-panel displays sometimes use dithering to provide a 4-value gray scale.

VGA -- Video-graphics array. An electronic display standard that specifies a resolution of 640 x 480 pixels with 16-color capability, and 320 x 200-pixel resolution with 256-color capability (from a palette of 256k colors) the arrray's functions are available on an add-in board as an adapter.

Viewing angle - The range of angles at which you can read a display, measured in angular degrees of distance from the perpendicular. A viewing angle of 120 deg., for example, lets you read the display at any angle from 0 to 60 degrees from a plane that is perpendicular to the surface of the display. A conical viewing angle lets you read from above, below, or either side of the display.

20 J001C JAPAN AVIATION ELECTRONICS

THEY HAVE DEMONSTRATED COLOR FLAT PANEL DISPLAYS WHICH ARE BEING DELIVERED TO BOEING FOR 757 AND 767 COCKPIT APPLICATIONS. THE 5"x5" HAVE 120 ROWS, WEIGH 7KG AND HAVE 0.4 RESOLUTION TOUCH SWITCH.

2 J0000 GAS DISCHARGE (PLASMA) DISPLAY PANELS

All plasma display panels (PDP) contain a gas, usually neon, that glows when subjected to a high voltage. In a dot-matrix display, this voltage is applied between two sets of electrodes; one set runs vertically, the other runs horizontally; the gas is in between the two. Plasma displays exhibit a characteristic orange or red-orange color. There are three basic plasma technologies: dc-refresh, ac-refresh, and ac-memory. The basic difference between the refresh types and ac-memory plasma displays is that the memory display includes dielectric layers: ac-memory displays

have dielectric layers that separate the gas from the activating electrodes. The dielectric in an ac-memory display restricts the electrodes to capacitive coupling with the gas, a condition that allows the gas to stay lit until another signal turns it off.

This action serves to create a kind of pixel which eliminates the need for screen refresh in ac-memory plasma displays. Both the ac- and dc-refresh types require refreshing at least once 1/60 of a second to prevent flickering.

Plasma displays are generally the most expensive because they require high voltage drivers (and perhaps a dc-dc converter) and they also consume more power than other flat panel technologies. PDP are most commonly used for military and other harsh environmental applications because their glass substrate is the thickest (strongest) and the envelope is hermetically sealed to maintain the gas integrity.

The basic design and current technology of plasma display panels does not offer promise of a multicolored display.

These devices are made in both commercial and ruggedized military versions. The militarized versions withstand operating temperatures of -60 to +85 deg C. and MIL-STD-810 shock and vibration. They have an operating life in excess of 50,000 hours and a mean time to repair (MTTR) of less than 25 minutes (for replacement). They offer both digital and analog video interfaces.

These panels come in sizes ranging from 10 centimeters to 1.5 meters (diagonal), and are typically less than 3 inches thick. They have a contrast ratio of 25:1 and a wide viewing angle, of up to 160 degrees. Their peak brightness is > 70 foot lamberts, and their average brightness is > 40 foot lamberts. They have no flicker, distrotion, ghosts or burn-in, and no brightness decay over time. They have an inherent memory and do not require computer refresh circuitry.

They will operate on a variety of power supplies from 28 VDC to 250 VAC, and can be provided with EMI/RFI shielding.

Touchscreen technologies of the IR crossbeam and membrane types can be incorporated.

54 J027F
27 J011A
15 J010A Fujitsu have extended the resolution of their ac plasma display panels from 640 x 400 (FPF-8050HFUGA) to 640 x 480 pixels (FPF8060HRUM) and both these sizes are now available with or without grey-scale. A larger resolution panel (1024 x 768 pixels) is under development. The 4-level grey-scale version of the 640 x 480 (FPF8060HRUK) has a display area of 211mm x 158mm (10.4in diagonal size) withhin an overall module size of 279mm x 213mm x 19mm deep. Unit weight is about 1kg. The brightness of 110cd/m^2 provides a CR of 20:1 and viewing angle of 120deg. The display utilises a 95v sustain voltage and a 2bit data scheme.

25 J003C
60 J030A
24 J003B
28 J012A
29 J013A
16 J010B Fujitsu have extended the resolution of their ac plasma display panels from 640 x 400 (FPF-8050HFUGA) to 640 x

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35 J019A
30 J014A
31 J015A
32 J016A
33 J017A
34 J018A
5 J001A THE FOLLOWING IS AN EXERPT FROM AN 8/86 TRIP REPORTWRITTEN BY THE OFFICE OF THE U.S. UNDER SECRETARY OFDEFENSE - SPONSORED ELECTRO-OPTIC/MILLIMETER WAVE/ MICROWAVE TEAM.

SONY DEMONSTARTED OUTSTANDING CAPABILITIES IN FLAT PANALDISPLAYS SHOWING 20"x20" FLAT CRT WITH 2048x2048 PIXELS.

10 J005A A 20 - inch diagonal color gas-discharge panel with640x448 cells and an average cell pitch of .65mm has beenexperimentally developed using thick-film printing andphotolithographic phosphor deposition technique. Theimprovements in both the cell structure and fabricationtechnique have produced wide memory margins for the pulsememory operation. Full size NTSC color TV pictures withexcellant uniformity have been displayed showing an arealuminance of 17fl and a luminous efficacy of 0.13lm/W.

3 J0000

ELECTROLUMINESCENT DISPLAYS

Electroluminescent displays (ELD)s depend on the properties of substances such as ZnS doped with Mn to luminesce when subjected to a high voltage. The higher the voltage, the brighter the luminance. This effect also can generate gray-scale images. A dot-matrix ELD consists of column electrodes behind a layer of luminescent material, with transparent row electrodes in front of the material. ELDs offer high resolution and exhibit a yellow-on-black display of high contrast that is pleasing to the eye. This type of flat panel is useful for applications that require both large-area displays and expanded information content, such as portable computers.

There are two basic types of ELDs: ac thin-film (ACTFEL) and dc thick-film (DCTFEL). Although both types can produce the same levels of light intensity, contrast, and resolution, manufacturers of each type claim certain cost or performance advantages. In the past, both types have shown signs of wearing out earlier than CRT counterparts, whose halflife is typically 10,000 hours. New materials and processing techiques, and the use of electronic circuitry, however, have largely eliminated these premature effects of extended use. ACTFEL displays, for example, used to show latent images on the screen as they got older, but symmetric driving circuits have overcome this problem.

The ac thin-film display is capacative in nature and its brightness is limited by drive voltage and by pulse repetition frequency, while the dc thick-film display is resistive in nature and its brightness is proportional to its constant drive current.

The drive circuitry of ELDs is critical to their performance and life. Interface ICs provide data and timing signals for the

constant-current column drivers, row drivers, and control signals. The frame rate for incoming video data is 60 Hz, and is 240 Hz for data output to the column drivers, which improves the brightness, and reduces power consumption.

7 J003A
22 J001C
55 J027H
4 J0000

LIQUID CRYSTAL DISPLAYS

In a twisted-nematic liquid crystal display (LCD), which is designated TNLCD, a liquid crystal mixture is sandwiched between two glass plates that are coated with a polarizer and lined with transparent electrodes. The application of an electric field shifts the nematic molecules so that they line up with the field, and so changes the molecules' optical characteristics. The refractive index of these molecules depends on their orientation relative to the direction of the incident light. In a standard LCD panel, the application of an appropriate (low) voltage aligns the crystals so that they either transmit or block the polarized light. A dichroic dye included in the crystal material colors the light that passes through it. In conventional TN-LCDs the liquid-crystal material imposes a 90 deg" rotation (twist) on the plane of polarized light passing through the display, and these displays have contrast ratios of less than 3:1 when viewed head on, and exhibit viewing angles of less than 40 deg .

A Super-twist LCD is a liquid-crystal display that rotates the plane of polarization in the range of 180 to 270 deg and uses an alignment layer in the display that provides a pre-tilt of from 10 to 30 deg which provides contrast ratios of about 10:1 and viewing angles as high as 60 deg. The super-twisted nematic (STN) LCD is produced in a configuration of 640 x 400 pixels.

The slow response time of the most often used STN liquid crystal materials (150-300 ms) contributes to its multiplexing limit and prevents its use for video and TV. The transmission of light through an STN LCD is wavelength dependent giving rise to colored modes of operation, such as blue characters on a yellow-green background. A wide variety of techniques are being developed to improve the performance of conventional STN LCD, including: increasing the twist angle, optimizing the birefringence and cell depth to minimize color effects. The use of two matched LC cells with opposite twist rotations to remove coloration has allowed the development of black/ white mode DST (double cell or neutralized) LCDs. Advantages of DST include a contrast ratio of >15:1, and a corresponding widening of viewing angle, at the expense of double the weight and a 50% increase in cost.

The neutralization of color effects in the STN LCD also makes possible the development of a low cost, large multicolored DST LCD. Another approach to multicolor LCD involves the active-matrix TFT LCD which incorporates a polycrystalline Si (silicon) deposition that requires a high temperature process which is incompatible with low-cost glass substrates. In this design, each pixel is equipped with a thin-film transistor (TFT) or diode switch. Electrodes are placed on the same glass panel with conductive paths for x and y lines. The adjacent liquid crystal layer acts as a dielectric to electrodes on the opposite glass plate, the entire sandwich forming a capacitor.

Compared to other flat panel technologies, LCDs are relatively inexpensive, consume very little power, and are thin, durable, and light-weight. Their major disadvantages are poor contrast, low brightness, and a reduction in performance as display size increases. The newer active-matrix types overcome some of these

disadvantages but, because each pixel requires a separate drive transistor, the display and the drive circuitry are more complicated (and expensive) than conventional types. Backlighting of LCDs, with either an electroluminescent or cold cathode fluorescent tube, is becoming common for applications where the ambient light level is low. While full color LCD panels are starting to emerge, the color quality does not match a cathode ray tube (CRT) because most LCD cannot display a gray scale, and the cost is 10 times that of a CRT. Most color LCDs use filters which increase the backlighting requirement by 5 times, and virtually restrict the panels to AC applications.

39 J023A IDEAL FOR DISPLAYS IN PERSONAL COMPUTERS, WORDPROCESSORS, POS TERMINALS, MEASURING INSTRUMENTS, ANDDATA TERMINALS.

40 J024A IDEAL FOR DISPLAYS IN PERSONAL COMPUTERS, WORDPROCESSORS, POS TERMINALS, MEASURING INSTRUMENTS, ANDDATA TERMINALS FOR THE DOMESTIC MARKETS.

68 J034A

36 J020A IDEAL FOR DISPLAYS IN PERSONAL COMPUTERS, WORDPROCESSORS, POS TERMINALS, MEASURING INSTRUMENTS, ANDDATA TERMINALS.

37 J021A

41 J025A

38 J022A IDEAL FOR DISPLAYS IN PERSONAL COMPUTERS, WORDPROCESSORS, POS TERMINALS, MEASURING INSTRUMENTS, ANDDATA TERMINALS.

12 J007A

62 J031C HITACHI REPORTS THAT IT IS SUCCESSFULLY MASS-PRODUCING ATFT DISPLAY FOR LAPTOP USE. WHILE THE DISPLAY RATES NOLESS THAN WONDERFUL, THE SCREEN MEASURES A SCANT 6.3INCHES DIAGONALLY AND OFFERS NO BETTER THAT CGA GRAPHICS.

69 J035A A FULL COLOR LASER ADDRESSED PROJECTION DISPLAY ISCONSTRUCTED BY EMPLOYING THREE SMETIC-A CRYSTALLIGHT-VALVE CELLS CORRESPONDING TO THREE PRIMARY COLORS.IN ORDER TO MINIMIZE REGISTRATION ERROR, A SINGLE SCANNEDLASER BEAM IS OPTICALLY IS DIVIDED INTO THREE BEAMS TOSCAN RGB LIQUID-CRYSTAL CELLS SYNCHRONOUSLY. FULL-COLORIMAGES WITH 1000x1000 PIXELS CAN BE WRITTEN INAPROXIMATELY 1 MINUTE BY USING THE RASTER-SCAN METHODWHILE MULTICOLOR IMAGES WITH 2000x2000 ADDRESSABLE PIXELSCAN BE WRITTEN AT A SPEED OF 30m/SEC ON A SCREEN BY USINGTHE VECTOR SCAN METHOD. THE 2x2M IMAGE HAS A BRIGHTNESSOF A 30f1 WHEN PROJECTED ONTO A 3.5 GAIN SCREEN.

58 J029A JAE is currently developing third generation, LCD colorflat panel displays for U.S. companies. They have nointerest in commercial TV markets, and are only workingon cockpit display systems. The current 1985 modelmeasures 5X5", has 120 dots/inch and displays 8 colors.It incorporates a .4 inch resolution touch switch. Thenext generation model will measure 6.7 x 6.7", have 150dots/inch, and also display 8 colors.

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6 J002A Liquid crystal panels are finding applications in liquid crystal TV and displays, and are now required to be larger and have more pixels.
The liquid crystal panel developed by Mitsubishi Electric is a direct on wafer (DSVV) type using a thin transistor (TFT) of 5um in length, and with about 860,000 pixels concentrated in a 10-inch screen.

The panel's characteristics are :

(i) The transistor pattern of 5um gate length is formed by exposure transfer by the DSW system use VLSI;

(ii) Silicon nitride film (insulation film) is double-layered to prevent short circuit in gate and source lines.

(iii) Metal wiring is double-layer structured to reduce line defects.

There are two liquid crystal drive systems the transference electrode system (simple matrix) and the TFT system (active matrix). The TFT system has fully demonstrated that a fine amorphous silicon TFT can be easily formed on a glass substrate by the DSW method, the circuit pattern forming technology for ICs and LSIs.

63 J031D MISUBISHI HA DEVELOPED A 10" DIAGONAL, TFT LCD XAPABLE OFDISPLAYING EIGHT COLORS AT A RESOLUTION OF 640x480. THECOMPANY DIVULGED NO DEFINITE PLANS TO MARKET A LAPTOPBASED ON THE DESIGN.

9 J004B The National Aerospace Laboratory (NAL) of the Science and Technology Agency, began an evaluation study on an integrated-type liquid crystal display. The display has been installed on an instrument panel in the cockpit of NAL's night simulator, and its functions and display forms are mainly being evaluated and compared with previous instruments by pilots.

What is cunently being evaluated is a 5-inch (127 mm) -square liquid crystal display made by Yokogawa Electric Corp. The liquid crystal display part itself was made by Seiko Epson Corp. (Main office: Suwa Ciyy, Nagano Prefecture). The liquid crystal display shows the function of an electronic attitude direction indicator(EADI). Displayed items concerning motions and the color of symbols have been evaluated and examined.

Since February 1989, NAL has evaluated the same liquid crystal display, using the night simulator which was acquired from the research progect on ASUKA," a short takeoff and landing experimental craft. According to pilots who have evaluated the display, it is easier to read than a CRT (Brown tube) because its background is not too bright, and the oblique reading from an adjacent seat, which used to be problematical with liquid crystal displays, is no longer a serious problem.

NAL plans to evaluate even larger-size liquid crystal displays. For this evaluation, two units of 8-inch (206 mm) square liquid crystal displays developed by Japan Aviation Electronics Industry, Ltd., will be used. One unit will be used as an attitude direction indicator, and the other will be made to function as a digital map display. These units will also be evaluated by pilots.

Besides Yokogawa Electric Corp. and Japan Aviation Electronics Industry, Ltd., NAL has invited other liquid crystal display manufacturers to participate in the evaluation project. Thus, it is possible to have more companies participate in the project.

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61 J031A PERFORMANCE OF PROSPEEDCSX LCD

* IMAGES FADE ON SCREEN
* MOVING CURSOR RESULTS IN GHOSTING
* BACKGROUND LOOKS WASHED OUT
* THE SCREEN SEEMS BLOTCHY AND HAD PROBLEMS WITH VERTICAL COLOR BLEEDING
* DISPLAY FALLS SHORT OF VGA COMPATIBILITY

23 J001D

14 J009A CONTRAST ENHANCED MODE (CEM) FOR ACTIVE MATRIX DISPLAYS

The authors have succeeded in the development of a newTC-LC mode, CEM, which is suitable for the application toactive matrix LCDs. By appling the CEM with a talanmixture, the Poly-Si TFT-LCD shows excellent imagequality with a high CR of more than 150, a high grayscale capability, a wide color producibility and a fastresponse time. We beleive that the CEM will lead to aremarkable improvement of image quality in TFT andMIM-LCDs and support the spread of active matrix LCDs.

21 J010C

11 J006A Seiko Epson Corporation has assembled a 12" color panelmodule. The out look of the panel is shown below.

SIZE	12"
DRIVING METHOD	MULTIPLEX-ADDRESSED WITH 16 HARMONIES
LIQUID CRYSTAL	NTN
DOTS	640x480
DUTY	1/240
PATTERN PITCH	SEG: 130um (COG) COM: 390um (TAB)

56 J028A
57 J028B
67 J033A
13 J008A

Table 1 Specifications and performances of the present LCD

Number of pixels	308,160 [642(H) x 480(V)]
Number of TFTs	1,232,640 [1,284(H) x 960(V)]
Pixel pitch (mm x mm)	0.41 (H) x 0.428(V)
Subpixel pitch (mm x mm)	0-205(H) x 0.214(V)
Screen size (mm x mm;	278(H) x 221 (V) [14" diagonal]
Color pixel arrangement	triangular
LC mode	TN Lnormally white]
Maximum contrast ratio	>100:1
Viewing angle Horizontal	120 deg C.R. > 10:1
Verticaal	50 deg C.R. > 10:1

Summary

A 14-in.-diagonal full color a-Si TFT-LCD has been developed by means of a new design of TFT arrangement andthe optimizations of the factors which dominates off-state characteristics. The display has 308,160(642Hx480V)pixels (1,232,640subpixels) and provides goodpictures by its high contrast ratio (more than 100:1 at the optimum viewing angle).

A new design of TFT arrangement adopted to the present display realizes high display quality and leads to high production yield at the same time owing to triangularpixel arrangement with straight bus lines.

51 J027C
50 J027E
49 J027A
52 J027D
26 J010D Toshiba's R & D also includes investigation of the smectic C phase. The investigations of wavelength dependence of transmission vercus cell depth and contrast ratio versus operating voltage for a multiplexed (1:400) display at 25deg C culminated in the fabrication of a 639x400 pixel, 12" diagonal RGB filtered multicolour display. It was found that to minimise transmission dependence on wavelength a 2um cell depth was appropriate while a 1 in 400 multiplex duty ratio could be obtained (that is 100us pulse response) for an operating voltage of 25V. The CR was >10:1 in the memory state although this decreases to 4:1 under operation because of the adverse influence of half-select waveforms.

It should be stressed that this technology is still at an early stage and a number of difficulties remain to be overcome before achieving commercially viable displays.

64 J031E ONE OF THE MOST PROMISING DEVELOPMENTS CAME WHEN TOSHIBAAND IBM JAPAN ANNOUNCED A JOINT VENTURE AIMEDSPECIFICALLY AT MASS-PRODUCING A TFT LCD THAT THECOMPANIES DEVELOPED IN ANOTHER COLLABORATIVE EFFORT. THEJOINT VENTURE WILL OPERATE UNDER THE NAME DISPLAYTECHNOLOGIES AND WILL FIRST MANUFACTURE A 10" VGA DISPLAYTHAT WILL BE SOLD TO BOTH IBM AND TOSHIBA FOR USE INTHEIR PC AND WORKSTATION PRODUCTS.

65 J032A A pair of Japanese companies has nudged the record for the largest active-matrix liquid-crystal display up to 14.26 inches. The new display, developed by IBM Japan Ltd. and Toshiba Corp., boasts resolution of 1,440 by 1,100 pixels in monochrome, and 720 by 550 pixels in color. Despite its area, the panel's dot pitch is a

tiny 200 um. But commercial production, which is two or three years away, won't be an easy task because it will probably take huge fabrication equipment to make the panels economically. What that means is that equipment must be able to turn out at least four to eight panels on one sheet of glass so that a single defect doesn't destroy the whole production run. That's why color TV sets with active-matrix panels are now limited to the 2- to 5-in. range.

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19 J0000

VACUUM FLUORESCENT DISPLAY PANELS

Vacuum fluorscent display (VFD) panels are well suited for applications that need only limited information content, such as dashboard displays in cars. For displays of less than about 200 characters, this type offers the best cost/character ratio. VFDs have a pleasant blue-green color that is usually brighter than either PDPs or ELDs. VFDs use essentially the same operating principle as a triode vacuum tube: The phosphor-coated anode segments radiate light when struck by electrons emmitted by the filament cathode, and a metal-mesh grid controls the flow of electrons from the cathode to the anode. Phosphor alignment problems for high-end applications tend to reduce production yields.

VFDs are moderately expensive, and dissipate a lot of power, but they rpoduce a lot of light and can be used in high ambient light applications. They are hermetically sealed and are suitable for use in humid applications, but their electrode structure makes them susceptible to shock and vibration damage.

One recently developed VFD has a pixel count of 640 x 400, a moderately high luminance (40 fL), and the blue green color can be modified by the use of filters.

44 J026C
45 J026D
46 J026E
47 J026F
48 J026G
43 J026B
53 J027E
42 J026A